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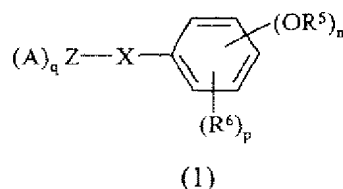
(71) Applicant: Cerebrus Pharmaceuticals Limited  
Winnersh, Wokingham RG41 5UA (GB)

(72) inventors:  
• Bebbington, David,  
Cerebrus Pharmaceuticals Ltd  
Winnersh, Wokingham RG41 5UA (GB)  
• Gaur, Suneel, Cerebrus Pharmaceuticals Ltd  
Winnersh, Wokingham RG41 5UA (GB)  
• Spencer, John, Cerebrus Pharmaceuticals Ltd  
Winnersh, Wokingham RG41 5UA (GB)

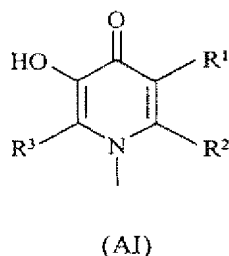
(74) Representative: Howard, Paul Nicholas et al  
Carpmaels & Ransford  
43 Bloomsbury Square  
London WC1A 2RA (GB)

(54) 3-Hydroxy-2(1H)-pyridinone or 3-hydroxy-4(1H)-pyridinone derivatives useful as reactive oxygen species (ROS) scavengers

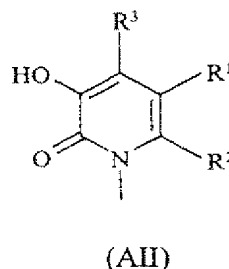
(57) A compound of the formula (1):



wherein A is



or



wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are independently selected from H and alkyl;  
wherein X is O, S, NR<sup>4</sup> or a direct bond, wherein R<sup>4</sup> is H or alkyl;  
wherein Z is a saturated hydrocarbyl chain comprising from 1 to 20 carbon atoms interrupted by one or more heteroatom(s) and optionally substituted by one or more oxo substituent(s);  
wherein q is 1, 2 or 3;  
wherein if q is 2 or 3, then each A can be the same or different;  
wherein the or each R<sup>5</sup> is independently selected from H and alkyl;

wherein the or each  $R^6$  is independently selected from alkyl;  
wherein n is 1 to 5;  
wherein p is 0 to 4; and  
wherein the sum of n and p is less than 6,

or a pharmaceutically acceptable salt thereof, and the use thereof in therapy, particularly for the treatment of a condition associated with oxidative stress, such as oxidative damage of the central nervous system or an acute or chronic neurological disorder such as traumatic brain injury, spinal cord injury, cerebral tumour, subharrachnoid haemorrhage/cerebral vasospasm, cerebral ischaemia, stroke (ischaemic or haemorrhagic), Alzheimer's disease, Huntington's Disease, Parkinson's Disease, Friedrich's ataxia, motor neuron disease or multiple sclerosis.

## Description

**[0001]** The present invention relates to compounds containing both ortho-hydroxypyridinone and oxygenated aryl functionalities, which possess the dual ability to chelate iron and scavenge reactive oxygen species (ROS). In particular, the invention relates to specific compounds containing a 3-hydroxy-4(1*H*)-pyridinone or a 3-hydroxy-2(1*H*)-pyridinone iron chelating moiety as well as a phenolic antioxidant moiety. The present invention also relates to the synthesis of such compounds, to pharmaceutical preparations comprising such compounds and to the use of such compounds in the treatment and prophylaxis of conditions associated with oxidative stress, particularly oxidative damage to the central nervous system.

**[0002]** One particularly relevant example of a condition involving oxidative damage to the central nervous system, which can be treated with compounds of the present invention, is stroke. Stroke is the third leading cause of death in major industrialised countries and the commonest cause of permanent disability (Hunter *et al.*, Trends in Pharmacological Sciences, 1995, 16, 123-128). Each year, in the US and Europe, approximately 1 million people suffer acute stroke (Dorman *et al.*, CNS Drugs, 1996, 5, 457-474). Between 25% and 35% of these patients die within the first three weeks, and of the survivors 25% to 50% will be totally dependant on family or institutional care for the rest of their lives. The incidence of stroke increases with age, roughly doubling with each passing decade, with 30% of persons aged over 65 years being affected (Babikian *et al.*, Cerebrovascular disease in the elderly. In Clinical Neurology of Aging, Eds Albert M.L. and Knoefel J.E., OUP, New York, 1994). These statistics translate into an annual incidence of 0.1 to 0.2% in the US and Europe, with the world-wide market for stroke estimated to be worth \$3 billion in 1995 and projected to rise to \$10 billion in 2005.

**[0003]** Stroke is defined as an interruption of the blood flow to the brain or leakage of blood out of the brain resulting in oxygen deprivation (ischaemia) and subsequent neuronal cell death. Strokes can be divided into two classes, ischaemic and haemorrhagic. The former accounts for approximately 83% of all strokes and is caused by thrombosis (65%) and/or detachment of a previously formed clot (embolus, 18%). Haemorrhagic strokes, which account for the remaining 17% of all strokes, can be subdivided into subarachnoid haemorrhage (7%) and cerebral haemorrhage (10%).

**[0004]** Markers of oxidative damage have been detected in the brains of ischaemic animals, and a variety of antioxidant molecules have been demonstrated to be neuroprotective in ischaemic stroke models. This provides conclusive evidence that cerebral ischaemia leads to the production of reactive free radicals. Defined as a chemical species containing one or more unpaired electrons, and capable of independent existence, free radicals are highly destructive towards cellular membrane lipids, DNA and proteins. This "oxidative-modification" of cellular components ultimately leads to a loss of cell function. One example of this oxidative process is lipid peroxidation (LP), a process which increases membrane fluidity leading to failure of normal membrane potential, disturbance of calcium homeostasis and transmembrane signalling, with the ultimate result of neuronal cell death.

**[0005]** A combination of the brain's high-energy demand and subsequent high rate of oxygen consumption, with its limited endogenous antioxidant defences (superoxide dismutase (SOD), glutathione peroxidase (GSPx), and catalase) makes the brain very susceptible to free radical attack. Additionally, neuronal cell membranes, being rich in polyunsaturated fatty acids, are especially vulnerable to oxidative modification. The brain's vulnerability to free radical attack is further exacerbated by relatively high levels of iron in the brain. Iron is the fundamental catalyst in the production of the hydroxyl radical ( $\cdot\text{OH}$ ) (Fenton and Haber-Weiss Reactions), reportedly the most destructive of all free radicals (Paimor, C., Metals and Oxidative Damage in Neurological Disorders, Ed. Connor, Plenum Press, New York, 1997, pp 205-236).

**[0006]** Exposure to free radicals is a natural consequence of aerobic respiration, to which the human body possesses a variety of natural antioxidant mechanisms. However, during pathological conditions such as stroke homeostatic mechanisms break down, and the balance between the generation of free radicals and natural antioxidant defences is shifted, resulting in a state of oxidative stress (Beal M.F., Ann. Neurol., 1995, 31, 119-130; Gerlach *et al.*, J. Neurochem., 1994, 63, 793-807).

**[0007]** In animal models of stroke, supplementation of antioxidant defences with exogenous antioxidant molecules has resulted in neuroprotection, as assessed both histologically and behaviourally (Hall E.H., Metals and Oxidative Damage in Neurological Disorders, *supra*, pp 325-339). Furthermore, transgenic animals overexpressing SOD have been demonstrated to be more resistant to cerebral ischaemia than their wild type littermates (Chan *et al.*, Ann. N.Y. Acad. Sci., 1994, 738, 93-103).

**[0008]** The iron chelator deferiprone (1,2-dimethyl-3-hydroxy-4(1*H*)-pyridinone) has also been shown to possess antioxidant properties. For example the use of deferiprone to inhibit free radical formation has been disclosed by Kontochiorghes *et al.* (Free Rad. Res. Comms., 1986, 2, 115-124) and by Mostert *et al.* (Free Rad. Res. Comms., 1987, 3, 379-388). The use of deferiprone in conjunction with an antioxidant is also disclosed in WO 94/03169 for use in the treatment of sickle cell disease, and by Antonius *et al.* (Circulation, 1989, 80, 158-164) for use in the prevention of postischemic cardiac injury. Deferiprone has recently been in clinical trials as a potential treatment for iron overload in

thalassemia major, and has also been disclosed for the treatment of parasitic infections, anemia and Alzheimer's disease.

[0009] There are many cellular systems known to be inappropriately activated or regulated as a result of oxygen starvation to the brain (e.g. glutamate receptors, voltage dependent ion channels). A major consequence of this is a loss of calcium homeostasis and inappropriate enzyme activation via several routes. Generation of free radicals is a common biochemical end point to many of the processes that are inappropriately regulated following cerebral ischaemia (Dorman *et al.*, *supra*, Hall E.H. *supra*; Patt *et al.*, J. Pediatric Surg., 1990, 25, 224-227). Hence intervention "down stream" with an antioxidant molecule at a point where many of these processes converge, is considered to be strategically sound owing to a universal applicability to many intracellular processes.

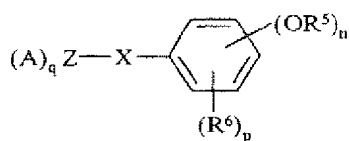
[0010] Based on the above rationale, a low molecular weight molecule designed to simultaneously trap radicals and chelate iron is a novel, scientifically relevant approach towards the treatment of conditions associated with oxidative stress, in particular cerebral ischaemia/stroke.

[0011] There have been three related reports describing molecular entities with dual iron chelating and anti-oxidant capabilities. The first report, Sato *et al* (Bioconjugate Chem., 1995, 6, 249-54), describes Cu,Zn-superoxide dismutase and desferrioxamine conjugated via polyoxyethylene. This high molecular weight conjugate was not used to show protection against oxidative stress *in vitro*, nor was it investigated for its effectiveness in *in vivo* models of oxidative stress. The second report, Rojanasakul *et al* (Biochim. Biophys. Acta, 1996, 1315(1), 21-8), describes a transferrin-catalase conjugate which gave increased protection to cells from oxidative stress as a result of its increased uptake in to cells *via* the transferrin receptor. The paper suggests the potential therapeutic use of the "...conjugate for the treatment of pathological processes in the lung". This high molecular weight conjugate was not investigated for its effectiveness in *in vivo* models of oxidative stress. The third report, Tilbrook *et al* (WO 9825905), claims compounds containing iron chelator units linked to a group containing reducing -SH groups for the treatment of Alzheimer's disease and related neurodegenerative diseases. The compounds were not investigated for their effectiveness in *in vivo* models of oxidative stress.

[0012] Currently there are only two recognised forms of treatment available for stroke victims. The first, Alteplase® (recombinant tissue plasminogen activator, rTPA) is a clot busting drug only suitable for cerebral thrombosis. Therapeutic thrombolysis can, however, be complicated by a) systemic haemorrhage, b) intracerebral haemorrhage, c) distal embolism of a partially digested clot leading to secondary infarction and d) cerebral oedema secondary to reperfusion injury. It is, therefore, necessary to exclude the possibility of haemorrhagic stroke by computerised tomographic (CT) scanning of patients before administering Alteplase. The second recognised treatment, carotid endarterectomy is a surgical procedure for unblocking the carotid artery. However, both treatments have the potential to exacerbate and complicate the original injury, and neither treatment is neuroprotective nor universal for all types of stroke. A third treatment, the antioxidant idebenone is licensed for the treatment of stroke in Japan. There is therefore a large unmet medical need for an effective neuroprotective compound for the treatment of stroke.

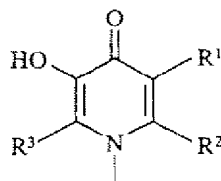
[0013] It is an object of this invention to provide compounds which, unlike the current therapies used for the treatment of stroke, protect against damage due to reperfusion injury, and are neuroprotective. Such compounds are potentially useful for all types of stroke. It is a further object of this invention to provide compounds which may be used in the treatment of oxidative stress generally and particularly oxidative damage to the central nervous system.

[0014] According to the present invention there is provided a compound of the formula (1):



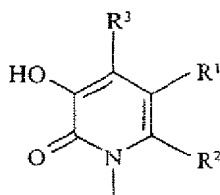
(1)

wherein A is



(AI)

or



(AII)

wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are independently selected from H and alkyl;

wherein X is O, S, NR<sup>4</sup> or a direct bond, wherein R<sup>4</sup> is H or alkyl;

wherein Z is a saturated hydrocarbyl chain comprising from 1 to 20 carbon atoms interrupted by one or more heteroatom(s) and optionally substituted by one or more oxo substituent(s);

wherein q is 1, 2 or 3;

wherein if q is 2 or 3, then each A can be the same or different;

wherein the or each R<sup>5</sup> is independently selected from H and alkyl;

wherein the or each R<sup>6</sup> is independently selected from alkyl;

wherein n is 1 to 5;

wherein p is 0 to 4; and

wherein the sum of n and p is less than 6,

or a pharmaceutically acceptable salt thereof.

**[0015]** It has been found that the compounds of the present invention which have a combined antioxidant and iron chelating activity can be used for treating oxidative stress, particularly oxidative damage to the central nervous system. It has further been found that the compounds of the present invention are surprisingly more effective, especially at low concentrations *in vitro*, than the simultaneous use of the separate ortho-hydroxypyridone iron chelating compound and the phenolic antioxidant compound.

**[0016]** As used herein, the term "alkyl" means a branched or unbranched, cyclic or acyclic, saturated or unsaturated (e.g. alkenyl or alkynyl) hydrocarbyl radical which may be substituted or unsubstituted. Where cyclic, the alkyl group is preferably C<sub>3</sub> to C<sub>12</sub>, more preferably C<sub>5</sub> to C<sub>10</sub>, more preferably C<sub>5</sub> to C<sub>7</sub>. Where acyclic, the alkyl group is preferably C<sub>1</sub> to C<sub>10</sub>, more preferably C<sub>1</sub> to C<sub>6</sub>, more preferably methyl, ethyl, propyl (n-propyl or isopropyl), butyl (n-butyl, isobutyl or tertiary-butyl) or pentyl (including n-pentyl and isopentyl), more preferably methyl. It will be appreciated therefore that the term "alkyl" as used herein includes alkyl (branched or unbranched), substituted alkyl (branched or unbranched), alkenyl (branched or unbranched), substituted alkenyl (branched or unbranched), alkynyl (branched or unbranched), substituted alkynyl (branched or unbranched), cycloalkyl, substituted cycloalkyl, cycloalkenyl, substituted cycloalkenyl, cycloalkynyl and substituted cycloalkynyl.

**[0017]** As used herein, the term "aryl" means a substituted or unsubstituted carbocyclic aromatic group, such as phenyl or naphthyl, or a substituted or unsubstituted heteroaromatic group containing one or more, preferably one, heteroatom, such as pyridyl, pyrrolyl, furanyl, thienyl, thiazolyl, isothiazolyl, oxazolyl, isoxazolyl, oxadiazolyl, thiadiazolyl, pyrazolyl, imidazolyl, triazolyl, pyrimidinyl, pyridazinyl, pyrazinyl, triazinyl, indolyl, indazolyl, quinolyl, quinazolyl,

benzimidazolyl, benzothiazolyl, benzisoxazolyl and benzisothiazolyl.

[0018] As used herein, the term "carbocyclic" refers to a ring system in which all the ring atoms are carbon atoms.

[0019] The alkyl and aryl groups may be substituted or unsubstituted. Where substituted, there will generally be 1 to 3 substituents present, preferably 1 substituent. Substituents may include:

carbon-containing groups such as

alkyl,

aryl,

arylkyl (e.g. substituted and unsubstituted phenyl, substituted and unsubstituted benzyl);

halogen atoms and halogen-containing groups such as

haloalkyl (e.g. trifluoromethyl);

oxygen-containing groups such as

alcohols (e.g. hydroxy, hydroxyalkyl, aryl(hydroxy)alkyl),

ethers (e.g. alkoxy, aryloxy, alkoxyalkyl, aryloxyalkyl),

aldehydes (e.g. carboxaldehyde),

ketones (e.g. alkylcarbonyl, alkylcarbonylalkyl, arylcarbonyl, arylalkylcarbonyl, arylcarbonylalkyl),

acids (e.g. carboxy, carboxyalkyl),

acid derivatives such as esters (e.g. alkoxycarbonyl, alkoxycarbonylalkyl, alkylcarbonyloxy, alkylcarbonyloxyalkyl),

amides (e.g. aminocarbonyl, mono- or di-alkylaminocarbonyl, aminocarbonylalkyl, mono- or di-alkylaminocarbonylalkyl, arylaminocarbonyl),

carbamates (e.g. alkoxycarbonylamino, aryloxy carbonylamino, aminocarbonyloxy, mono- or dialkylaminocarbonyloxy, arylaminocarbonyloxy)

and ureas (e.g. mono- or di-alkylaminocarbonylamino or arylaminocarbonylamino);

and nitrogen-containing groups such as

amines (e.g. amino, mono- or di-alkylamino, aminoalkyl, mono- or di-alkylaminoalkyl).

[0020] As used herein, the term "alkoxy" means alkyl-O-. Alkoxy substituent groups or alkoxy-containing substituent groups may be substituted by one or more alkyl groups.

[0021] As used herein, the term "halogen" means a fluorine, chlorine, bromine or iodine radical, preferably a fluorine or chlorine radical.

[0022] In a preferred embodiment, the alkyl groups are either unsubstituted or substituted by substitution of a hydrogen atom with a group selected from  $OR^7$ ,  $OCOR^7$ ,  $COOR^7$ ,  $NHR^7$ ,  $NHCO R^7$  and  $CONHR^7$  wherein  $R^7$  is H or alkyl.

[0023] As used herein, the term "heteroatom" means an atom other than a carbon atom, such as nitrogen, oxygen or sulphur.

[0024] As used herein, the term "oxo substituent" means an oxygen atom joined to a carbon atom or to a heteroatom, such as sulphur, in the hydrocarbyl chain by a double bond.

[0025] As used herein, the term "interrupted by one or more heteroatom(s)" means that the or each heteroatom may be positioned at any position along the hydrocarbyl chain including at either end of the chain.

[0026] As used herein, the term "interrupted by one or more group(s)", the group(s) being selected from O, S, SO, SO<sub>2</sub>, SO<sub>2</sub>NH, NHO<sub>2</sub>, NH, NHCO, CONH, NHCONH, NHCOO, OCONH, OCO and COO, means that the or each group may be positioned at any position along the hydrocarbyl chain including at either end of the chain.

[0027] As used herein, the term "pharmaceutically acceptable salt" means any pharmaceutically acceptable salt of the compound of formula (1). Salts may be prepared from pharmaceutically acceptable non-toxic acids and bases including inorganic and organic acids and bases. Such acids include acetic, benzenesulfonic, benzoic, camphorsulfonic, citric, ethenesulfonic, dichloroacetic, fumaric, gluconic, glutamic, hippuric, hydrobromic, hydrochloric, isethionic, lactic, maleic, malic, mandelic, methanesulfonic, mucic, nitric, pantoic, pantothenic, phosphoric, succinic, sulfuric, tartaric, oxalic, p-toluenesulfonic and the like. Particularly preferred are hydrochloric, hydrobromic, phosphoric, sulfuric and methanesulfonic acids, and most particularly preferred is the methanesulfonate salt. Acceptable base salts include alkali metal (e.g. sodium, potassium), alkaline earth metal (e.g. calcium, magnesium) and aluminium salts.

[0028] According to the present invention, the or each A may be independently linked to the chain Z at any atom of the chain Z. It is preferred that the or each A is independently linked to the chain Z at a carbon, nitrogen or oxygen

atom of the chain Z.

**[0029]** According to the present invention, when A is Al, preferably  $R^2$  and  $R^3$  are independently selected from H, unsubstituted alkyl,  $CH_2OR^7$ ,  $CH_2OCOR^7$ ,  $COOR^7$ ,  $CH_2NHR^7$ ,  $CH_2NHCOR^7$  and  $CONHR^7$  wherein  $R^7$  is H or alkyl. Preferably,  $R^1$  is selected from H and unsubstituted alkyl. More preferably,  $R^1$ ,  $R^2$  and  $R^3$  are independently selected from H and unsubstituted alkyl. More preferably,  $R^1$  and  $R^2$  are H and  $R^3$  is unsubstituted alkyl. It is further preferred that  $R^3$  is methyl.

**[0030]** According to the present invention, when A is All, preferably  $R^1$ ,  $R^2$  and  $R^3$  are independently selected from H, unsubstituted alkyl,  $CH_2OR^7$ ,  $CH_2OCOR^7$ ,  $COOR^7$ ,  $CH_2NHR^7$ ,  $CH_2NHCOR^7$  and  $CONHR^7$  wherein  $R^7$  is H or alkyl. Preferably,  $R^1$ ,  $R^2$  and  $R^3$  are independently selected from H and unsubstituted alkyl. More preferably,  $R^1$ ,  $R^2$  and  $R^3$  are H.

**[0031]** Preferably, the present invention provides a compound wherein A is Al.

**[0032]** Preferably, the present invention provides a compound wherein  $q=1$ .

**[0033]** In a preferred embodiment, Z is a saturated hydrocarbyl chain comprising from 1 to 20 carbon atoms interrupted by one or more group(s) selected from O, S, SO,  $SO_2$ ,  $SO_2NH$ ,  $NHSO_2$ , NH,  $NHCO$ , CONH,  $NHCONH$ ,  $NHCOO$ ,  $OCONH$ , OCO and COO.

**[0034]** Preferably, the present invention provides compounds wherein Z comprises from 1 to 13 carbon atoms.

**[0035]** In an alternative embodiment, the present invention provides compounds wherein Z comprises from 1 to 10, preferably from 1 to 8, carbon atoms.

**[0036]** In a further preferred embodiment, Z is  $(CH_2)_k W(CH_2)_m$ , wherein k and m are independently 0 to 20; wherein  $1 \leq (k+m) \leq 20$ ; and wherein W is selected from O, S, SO,  $SO_2$ ,  $SO_2NH$ ,  $NHSO_2$ , NH,  $NHCO$ , CONH,  $NHCONH$ ,  $NHCOO$ ,  $OCONH$ , OCO and COO. In this embodiment, it is preferred that:

when k is 0, W is selected from O, NH,  $NHCO$ ,  $NHCONH$ ,  $NHCOO$  and  $OCONH$ ; and

when k is 1, W is selected from SO,  $SO_2$ ,  $SO_2NH$ , CONH and COO; and

when m is 0 and X is a direct bond, W is selected from O, S,  $SO_2NH$ , NH, CONH,  $NHCONH$ ,  $NHCOO$ ,  $OCONH$  and COO; and

when m is 0 and X is O, S or  $NR^4$ , W is selected from SO,  $SO_2$ ,  $NHSO_2$  and  $NHCO$ ; and

when m is 1 and X is O, S or  $NR^4$ , W is selected from SO,  $SO_2$ ,  $NHSO_2$  and  $NHCO$ , OCO.

**[0037]** Preferably, the present invention provides compounds wherein  $1 \leq (k+m) \leq 13$ .

**[0038]** In an alternative embodiment, the present invention provides compounds wherein  $1 \leq (k+m) \leq 10$ , and preferably wherein  $1 \leq (k+m) \leq 8$ .

**[0039]** Preferably, the present invention provides compounds wherein k is 1, 2, 3 or 4. Preferably, m is 1, 2, 3 or 4.

**[0040]** Preferably, the present invention provides compounds wherein W is selected from O, NH, CONH,  $NHCO$ , COO and OCO. More preferably, W is selected from O, NH, CONH and  $NHCO$ .

**[0041]** According to the present invention, the chain Z may be branched or unbranched, optionally substituted by one or more alkyl group(s), and may be cyclic. Preferably, Z is an unbranched chain. It will be appreciated that where  $q=1$ , Z is a di-valent hydrocarbyl chain; where  $q=2$ , Z is a tri-valent hydrocarbyl chain; and where  $q=3$ , Z is a tetra-valent hydrocarbyl chain.

**[0042]** As used herein to describe the hydrocarbyl chain Z, the term "cyclic" means either that Z may comprise a cyclic hydrocarbyl group of from 3 to 10 carbon atoms, preferably 5, 6 or 7 carbon atoms; or that, where  $R^5$  or  $R^6$  is alkyl, a cyclic group is present as a result of cyclisation of the alkyl group of  $R^5$  or  $R^6$  onto Z; or that, where X is  $NR^4$  and  $R^4$  is alkyl, a cyclic group is present as a result of cyclisation of  $R^4$  onto Z. It is preferred that a cyclic group formed as a result of cyclisation of  $R^4$ ,  $R^5$  or  $R^6$  onto Z is a 5, 6 or 7-membered ring.

**[0043]** Preferably, the present invention provides compounds wherein X is O, S or a direct bond, more preferably X is O or a direct bond.

**[0044]** According to the present invention, where X is  $NR^4$ ,  $R^4$  is preferably alkyl.

**[0045]** According to the present invention, when X is  $NR^4$  and  $R^4$  is alkyl,  $R^4$  may be cyclized onto the chain defined as Z.

**[0046]** According to the present invention,  $R^5$  is preferably selected from H and  $C_{1-10}$  alkyl. More preferably,  $R^5$  is H. It is preferred that at least one  $R^5$  is H.

**[0047]** Preferably, the present invention provides compounds wherein n is 1 to 3, more preferably n is 1 or 2.

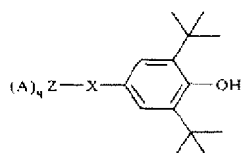
**[0048]** According to the present invention, when  $R^5$  is H, preferably  $OR^5$  is positioned in the ortho or para position in the ring with respect to X. More preferably,  $OR^5$  is positioned in the para position of the ring with respect to X.

**[0049]** According to the present invention, the or each  $R^6$  is preferably independently selected from  $C_{1-10}$  alkyl, preferably  $C_{1-4}$  alkyl, most preferably methyl, isopropyl or t-butyl.

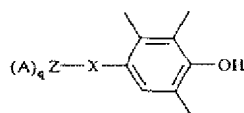
**[0050]** Preferably, the present invention provides compounds wherein p is 2, 3 or 4.

**[0051]** According to the present invention, when p is 1 or 2, alkyl groups represented by  $R^6$  is/are preferably positioned

ortho to OR<sup>5</sup>, preferably in the meta-position of the ring with respect to X to give, for example, a compound of formula:-



**[0052]** According to the present invention, when p is 3, alkyl groups represented by R<sup>6</sup> are preferably positioned to give, for example where three R<sup>6</sup> are methyl, a compound of formula:-

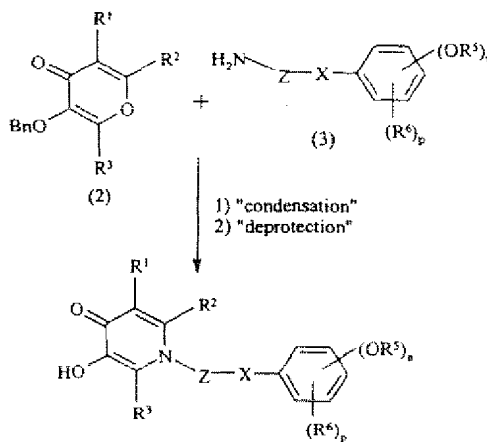


**[0053]** In an embodiment of the present invention, where R<sup>5</sup> or R<sup>6</sup> are alkyl, the alkyl group of R<sup>5</sup> or R<sup>6</sup> can be cyclized on to a carbon atom or a nitrogen atom of the chain defined as Z to form a ring.

**[0054]** According to a further aspect of the present invention there is provided a method of preparing the compounds of the present invention. The compounds of the present invention may be prepared using standard synthetic chemistry.

**[0055]** A general method for synthesis of compounds where q = 1 and A is a 3-hydroxy-4(1H)-pyridinone moiety comprises condensation of the primary amine of the respective antioxidant unit (3) with a 3-benzyloxy-4-pyrone (2) (in the presence of base, for example NaOH in a MeOH:water solution), followed by removal of the benzyl protecting group (with for example H<sub>2</sub> and Pd/C), as illustrated in Reaction Scheme 1. (For the condensation of 3-benzyloxy-2-methyl-4-pyrone with simple primary amines, see Dobbin *et al.*, J. Med. Chem., 1993, 36, 2448-2458).

### Reaction Scheme 1



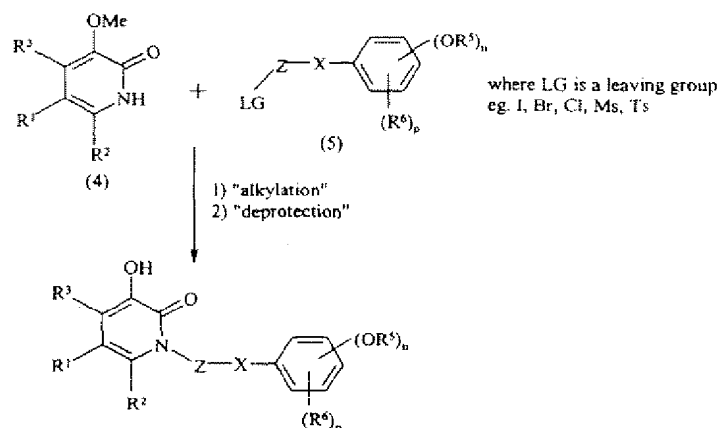
**[0056]** The primary amines, of the respective antioxidants, (3) can be prepared using standard synthetic chemistry.

**[0057]** A general method for synthesis of compounds where q = 1 and A is a 3-hydroxy-2(1H)-pyridinone moiety comprises N-alkylation of a 3-methoxy-2(1H)-pyridinone (4) with the halide of the respective antioxidant unit (5) (or an alternative electrophilic alkylating derivative of the antioxidant unit; for example, mesylate or tosylate), followed by removal of the methyl protecting group (with for example BBr<sub>3</sub>), as illustrated in Reaction Scheme 2. (For the alkylation



of 3-methoxy-2-(1*H*)-pyridinone with simple alkyl iodides, see Dobbin *et al.*, J. Med. Chem., 1993, 36, 2448-2458).

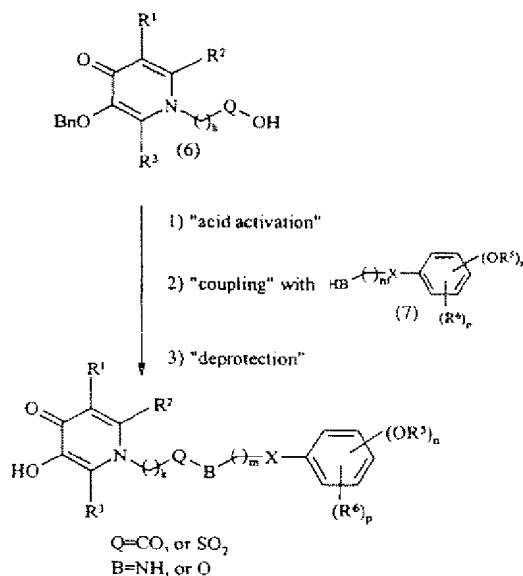
### Reaction Scheme 2



[0058] The primary halides, (mesylates and tosylates) of the antioxidants, (5) can be prepared using standard synthetic chemistry.

[0059] A specific method for the synthesis of compounds where  $q = 1$ , A is a 3-hydroxy-4-(1*H*)-pyridinone moiety and Z contains a CONH, COO, SO<sub>2</sub>NH or SO<sub>2</sub>O unit (for example, compounds of Example 1, 5 and 10) comprises coupling the acid derivative (carboxylic or sulfonic) of the protected hydroxy pyridinone (6) with the primary amine or alcohol of the respective antioxidant unit (7) using standard coupling techniques (for example via acid activation as a succinimide ester, or with coupling reagents such as EDCI), followed by removal of the benzyl protecting group, as illustrated in Reaction Scheme 3. (For the coupling of a compound of the type (6), where  $k$  is 2 and Q is CO, to simple amines see Dobbin *et al.* J. Med. Chem., 1993, 36, 2448-58).

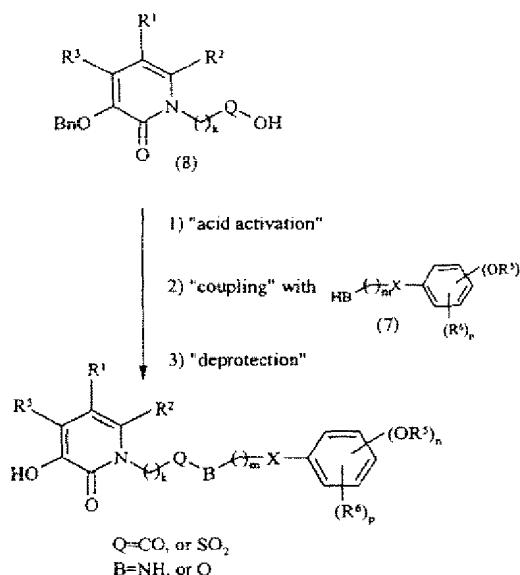
### Reaction Scheme 3



[0060] The acid derivatives (carboxylic or sulfonic) of the protected hydroxy pyridinones (6) can be prepared using standard synthetic chemistry. (For the synthesis of (6), where  $R^1$  and  $R^2$  are H,  $R^3$  is methyl,  $k$  is 2 and 3 and  $Q$  is CO, see Dobbin *et al.* J. Med. Chem., 1993, 36, 2448-58).

[0061] A specific method for the synthesis of compounds where  $q = 1$ ,  $A$  is a 3-hydroxy-2-(1*H*)-pyridinone moiety and  $Z$  contains a CONH, COO, SO<sub>2</sub>NH or SO<sub>2</sub>O unit (for example, the compound of Example 11) comprises coupling of the acid derivative (carboxylic or sulfonic) of the protected hydroxy pyridinone (8) with the primary amine or alcohol of the respective antioxidant unit (7) using standard coupling techniques (for example via acid activation as a succinimidyl ester, or with coupling reagents such as EDCI), followed by removal of the benzyl protecting group, as illustrated in Reaction Scheme 4. (For the coupling of a compound of the type (8), where  $k$  is 1 and  $Q$  is CO, to simple amines see Streater *et al.* J. Med. Chem., 1990, 33, 1747-1755).

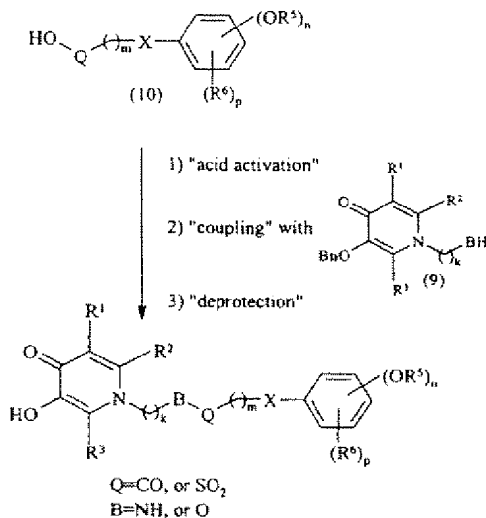
#### Reaction Scheme 4



[0062] The acid derivatives (carboxylic or sulfonic) of the protected hydroxy pyridinone (8) can be prepared using standard synthetic chemistry. (For the synthesis of (8), where  $R^1$ ,  $R^2$  and  $R^3$  are H,  $k$  is 1 and  $Q$  is CO, see Streater *et al.* J. Med. Chem., 1990, 33, 1747-1755).

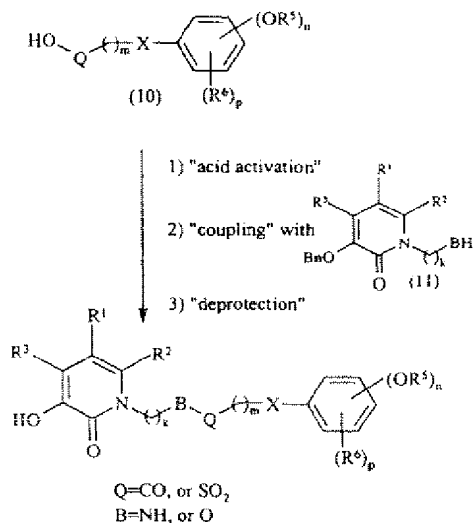
[0063] The primary amines and alcohols of the respective antioxidants (7) can be prepared using standard synthetic chemistry.

[0064] A specific method for the synthesis of compounds where  $q = 1$ ,  $A$  is a 3-hydroxy-4-(1*H*)-pyridinone moiety and  $Z$  contains a NHCO, OCO, NHSO<sub>2</sub> or OSO<sub>2</sub> unit (for example, the compounds of Example 3, 4, 8 and 9) comprises coupling the primary amine or alcohol derivative of the protected hydroxy pyridinone (9) with the carboxylic or sulfonic acid derivative of the respective antioxidant unit (10) using standard coupling techniques (for example via acid activation as a succinimidyl ester, or with coupling reagents such as EDCI), followed by removal of the benzyl protecting group, as illustrated in Reaction Scheme 5. (For the coupling of a compound of the type (9), where  $k$  is 3 and  $B$  is NH, to simple acid derivatives see Miller *et al.* Synth. Comm., 1995, 25, 3247-53).

**Reaction Scheme 5**

[0065] The primary amine or alcohol of the protected hydroxy pyridinone (9) can be prepared using standard synthetic chemistry. (For the synthesis of (9), where  $\text{R}^1$  and  $\text{R}^2$  are H,  $\text{R}^3$  is Me,  $k$  is 2 and 3 and B is NH and O, see Dobbin *et al.* J. Med. Chem., 1993, 36, 2448-58).

[0066] A specific method for the synthesis of compounds where  $q = 1$ , A is 3-hydroxy-2-(1H)-pyridinone moiety and Z contains a NHCO, OCO, NHSO<sub>2</sub> or OSO<sub>2</sub> comprises coupling the primary amine or alcohol derivative of the protected hydroxy pyridinone (11) with the carboxylic or sulfonic acid derivative of the respective antioxidant unit (10) using standard coupling techniques (for example via acid activation as a succinimide ester, or with coupling reagents such as EDCI), followed by removal of the benzyl protecting group, as illustrated in Reaction Scheme 6.

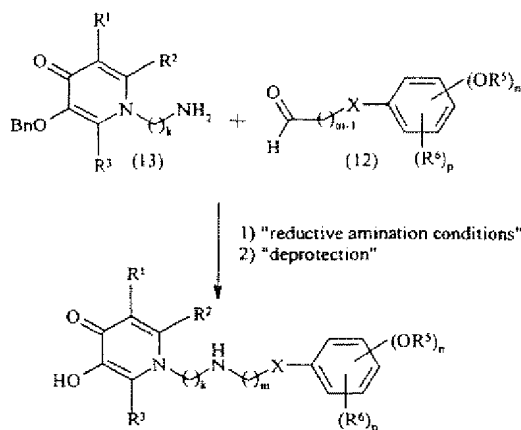
**Reaction Scheme 6**

[0067] The primary amine or alcohol of the protected hydroxy pyridinone (11) can be prepared using standard synthetic chemistry.

[0068] The acid derivatives (carboxylic or sulfonic) of the respective antioxidants (10) can be prepared using standard synthetic chemistry.

[0069] A specific method for the synthesis of compounds where  $q = 1$ , A is a 3-hydroxy-4-(1*H*)-pyridinone moiety and Z contains a NH unit (for example, the compounds of Example 2 and 7) comprises reductive amination of the aldehyde of the respective antioxidant unit (12) with the primary amine of the protected hydroxy pyridinone (13) using standard conditions (for example  $\text{NaCNBH}_4$  in MeOH), followed by removal of the benzyl protecting group, as illustrated in Reaction Scheme 7. (Alternatively, the reductive amination can be carried out in the reverse fashion using the aldehyde of the hydroxy pyridinone and the amine of the antioxidant unit.).

### Reaction Scheme 7

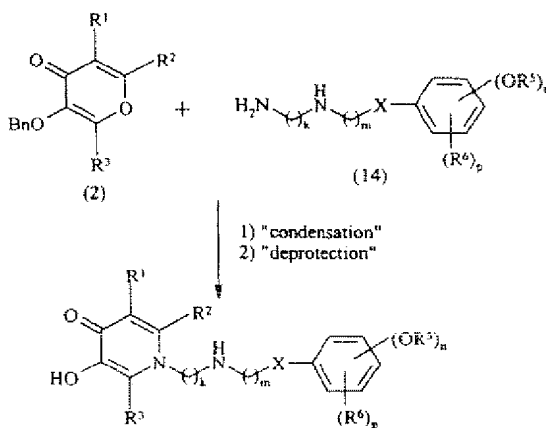


[0070] The primary amine of the protected hydroxy pyridinone (13) can be prepared using standard synthetic chemistry. (For example, for the synthesis of (13), where  $R^1$  and  $R^2$  is H,  $R^3$  is Me,  $k$  is 2 and 3, see Dobbin *et al.* J. Med. Chem., 1993, 36, 2448-58).

[0071] The aldehydes of the respective antioxidants (12) can be prepared using standard synthetic chemistry.

[0072] A second specific method for the synthesis of compounds where  $q = 1$ , A is a 3-hydroxy-4-(1*H*)-pyridinone moiety and Z contains a NH unit (for example, the compounds of Example 2 and 7) comprises condensation of the bis-amine of the respective antioxidant unit (14) with the 3-benzyloxy-4-pyrone (2), followed by removal of the benzyl protecting group, as illustrated in Reaction Scheme 8.

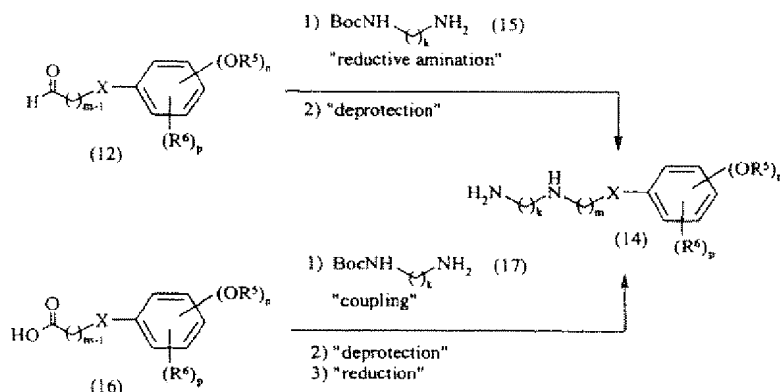
### Reaction Scheme 8



[0073] Bis-amine (14) can be prepared via standard methods. For example via reductive amination of the aldehyde derivative of the respective antioxidant unit (12) with di-aminoalkane (15) (using for example  $\text{NaCNBH}_4$  in MeOH), followed by deprotection (using for example trifluoroacetic acid). Alternatively (14) can be formed via amidation of the acid derivative of the respective antioxidant unit (16) with di-aminoalkane (17), followed by deprotection, and finally

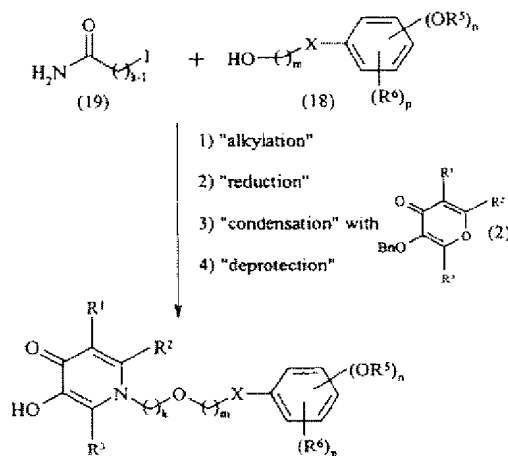
reduction (using for example  $\text{LiAlH}_4$ ). See Reaction Scheme 9.

### Reaction Scheme 9

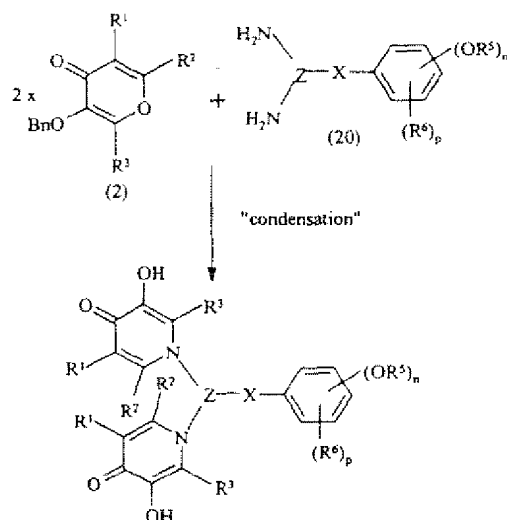


[0074] A specific method for the synthesis of compounds where  $q = 1$ , A is a 3-hydroxy-4-(1H)-pyridinone moiety and Z contains O units (for example, the compound of Example 6) comprises alkylation of the alcohol of the respective antioxidant unit (18) with an alkylating agent containing a nitrogen functionality (or a functionality capable of transformation into an amine group), for example compound (19), conversion of the product into an amine (using for example  $\text{LiAlH}_4$ ), condensation of the amine with the 3-benzoyloxy-4-pyrone (2), followed by removal of the benzyl protecting group. See Reaction Scheme 10.

### Reaction Scheme 10

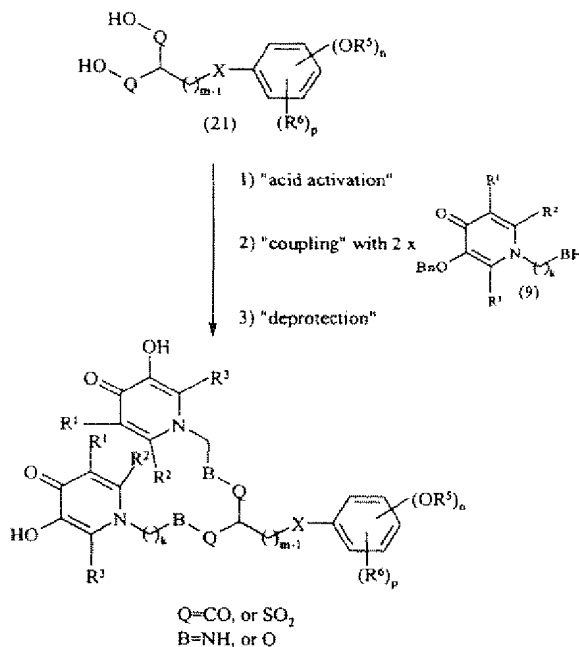


[0075] Compounds of the present invention which contain more than one hydroxy-pyridinone Fe-chelating unit (where  $q = 2$  or  $3$ ) may be prepared via a general method, using standard synthetic chemistry. For example, compounds where  $q = 2$  can be prepared via condensation of the bis-primary amine of the respective antioxidant unit (20) with two equivalents of the 3-benzoyloxy-4-pyrone (2) (in the presence of base, for example  $\text{NaOH}$  in a  $\text{MeOH}$ :water solution), followed by removal of the benzyl protecting groups (with for example  $\text{H}_2$  and  $\text{Pd/C}$ ), as illustrated in Reaction Scheme 11. Likewise, compounds where  $q = 3$  can be prepared via condensation of a tris-primary amine of the respective antioxidant unit with three equivalents of 3-benzoyloxy-4-pyrone (2). (For the reaction of (2), where  $\text{R}^1$  and  $\text{R}^2$  are H, and  $\text{R}^3$  is Me, with 1,6-diaminohexane see Orvig *et al.*, Can. J. Chem., 1988, 66, 123-131).

**Reaction Scheme 11**

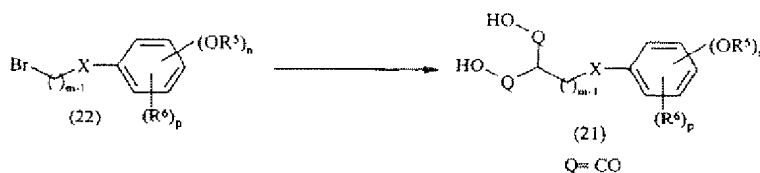
[0076] The bis-primary amine (20), (and tris-primary amines) may be prepared using standard synthetic chemistry.

[0077] A specific method of synthesis of compounds of the present invention which contain more than one hydroxy-pyridinone Fe-chelating unit, (where q = 2 or 3) and Z contains a NHCO, OCO, NHSO<sub>2</sub> or OSO<sub>2</sub> unit, exists. For example, synthesis of compounds where q = 2 comprises coupling two equivalents of the primary amine or alcohol derivative of the protected hydroxy pyridinone (9) with the di-carboxylic or di-sulfonic acid derivative of the respective antioxidant unit (21) (using standard coupling techniques, for example via acid activation as a succinimyl ester, or with coupling reagents such as EDCI), followed by removal of the benzyl protecting group. See Reaction Scheme 12. Likewise, compounds where q = 3 can be prepared via coupling a tris-carboxylic acid of the respective antioxidant unit with three equivalents of the primary amine or alcohol derivative of the protected hydroxy pyridinone (9).

**Reaction Scheme 12**

[0078] The di-carboxylic acid derivative of the antioxidant unit (21) can be prepared from bromide (22) via reaction with dimethylmalonate (in the presence of a suitable base, for example NaH) to produce the dimethylester, followed by saponification (using for example NaOH), as illustrated in Reaction Scheme 13.

### Reaction Scheme 13



[0079] Phenolic -OH groups of the antioxidant unit starting materials/precursors, described above, can be optionally protected during synthetic manipulation (for example, as a benzyl ether). Deprotection to reveal the phenolic -OH groups of the antioxidant unit can be carried out simultaneously with removal of the protecting group of the hydroxy pyridinone unit, in the last step of the sequence.

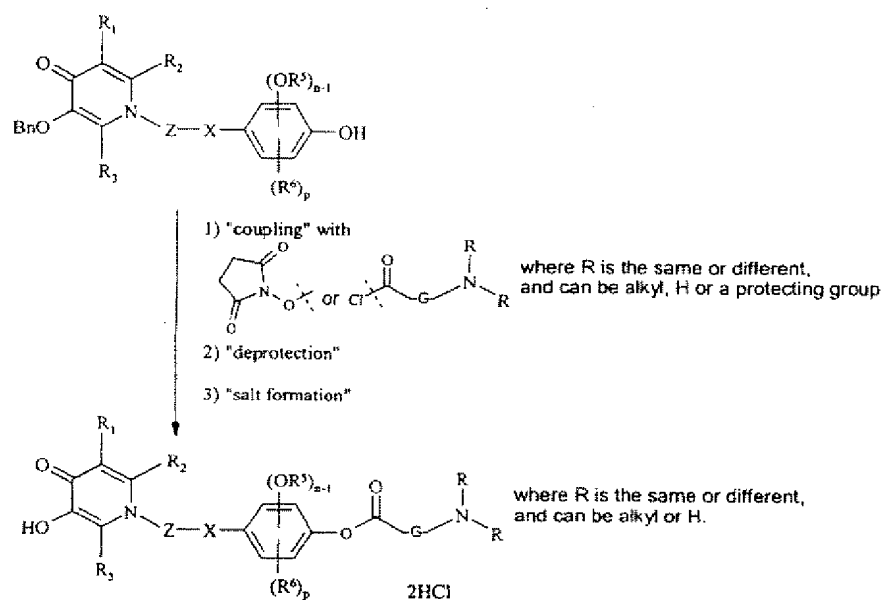
[0080] The compounds of the present invention may contain one or more asymmetric carbon atoms, so that the compounds exist in different stereoisomeric forms. The compounds can be, for example, racemates or optically active forms. The optically active forms can be obtained by resolution of the racemates or by asymmetric syntheses.

[0081] The compounds of the present invention may also be in a prodrug form wherein some or all of the free -OH groups of the preferred compounds are derivatised (for example, via an ester, amide or phosphate bond) with a suitable group (the group may contain, for example, an alkyl, aryl, phosphate, sugar, amine, glycol, sulfonate or acid function) which is suitably labile so as it will be removed / cleaved (eg. by hydrolysis) to reveal the preferred compound sometime after administration or when exposed to the desired biological environment. Prodrug forms of the compounds of the present invention can be used to increase compound solubility and stability for formulation, increase efficacy and decrease metabolism.

[0082] Preferably the prodrug forms of the compounds of the present invention are ester linked alkyl or aryl amines. For example, esters derived from glycine, N-methyl glycine, N,N-dimethyl glycine,  $\beta$ -alanine,  $\gamma$ -aminobutyric acid, valine, or aminobenzoic acid.

[0083] Preferably the ester linked amine prodrug is derived from N,N-dimethyl glycine.

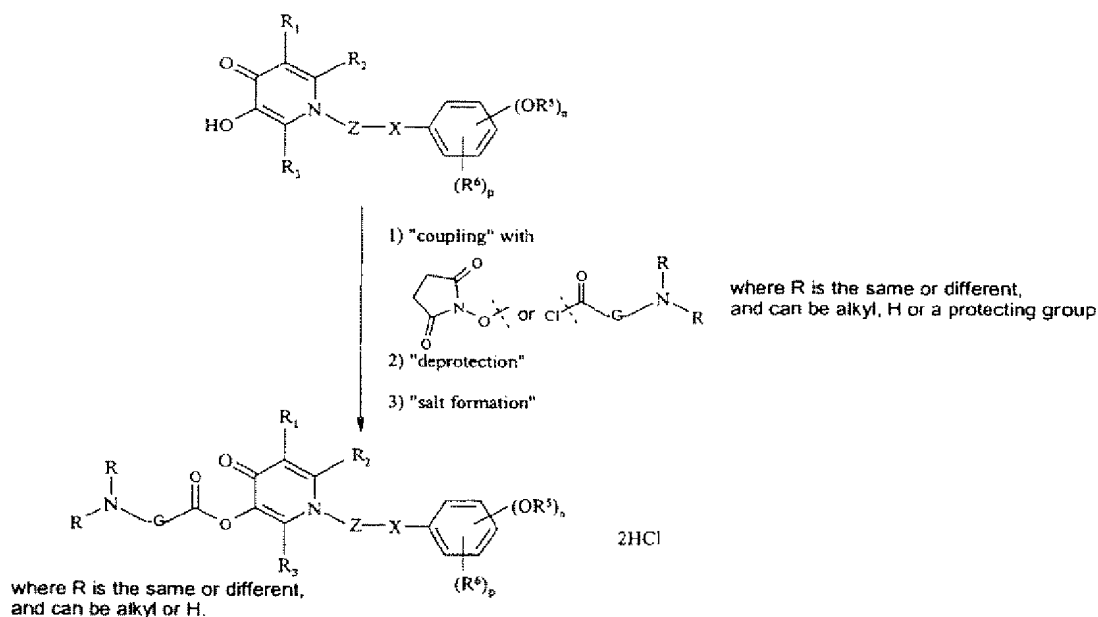
[0084] The prodrugs of the compounds of the present invention may be prepared using conventional synthetic methods. For example, a general method for synthesis of the preferred prodrugs of the compounds of the present invention comprises coupling a N-protected amino acid derivative with the hydroxy group of the antioxidant unit (using for example potassium carbonate in acetone), followed by deprotection. This is illustrated in Scheme 14 using a N-hydroxysuccinimide ester or an acid chloride as an example of the N-protected amino acid derivative.

**Reaction Scheme 14**

G = a bivalent hydrocarbyl chain, substituted or unsubstituted, such as an alkylene or arylene group

[0085] Alternatively, the N-protected amino acid derivative can be coupled to the hydroxy group of the pyridone unit, followed by deprotection, as illustrated in Scheme 15.



**Reaction Scheme 15**

G = a bivalent hydrocarbyl chain, substituted or unsubstituted, such as an alkylene or arylene group

[0086] Schemes 14 and 15 illustrate the preparation of prodrugs of the compounds of the present invention where A = Al and q = 1. However, the synthetic routes shown in Schemes 14 and 15 are generally applicable to the preparation of prodrugs of any of the compounds of the present invention, i.e. where A = Al or All and q = 1, 2 or 3.

[0087] To further increase their efficacy, compounds of the present invention may also contain additional non-covalently linked components such as dextrans or cyclodextrins, which aid stability and dispersion, and decrease metabolism of the active ingredient.

[0088] According to a further aspect of the present invention there is provided a compound of the present invention for use in therapy.

[0089] According to a further aspect of the present invention there is provided use of a compound of the present invention in the manufacture of a medicament for the treatment of a condition associated with oxidative stress, particularly oxidative damage of the central nervous system.

[0090] The term "treatment" as used herein includes prophylaxis.

[0091] Diseases, disorders and medical treatments/procedures associated with oxidative stress that can be treated with the compounds of the present invention include: aging; acute intermittent porphyria; adriamycin-induced cardiomyopathy; AIDS dementia and HIV-1 induced neurotoxicity; Alzheimer's disease; atherosclerosis; cataract; cerebral ischaemia; cerebral palsy; cerebral tumour; chemotherapy-induced organ damage; cisplatin-induced nephrotoxicity; coronary artery bypass surgery; diabetic neuropathy; Down's syndrome; drowning; epilepsy and post-traumatic epilepsy; Friedrich's ataxia; frontotemporal dementia; glaucoma; glomerulopathy; haemochromatosis; haemodialysis; haemolysis; haemolytic uraemic syndrome (Weil's disease); haemorrhagic stroke; heart attack and reperfusion injury; Huntington's disease; Lewy body disease; intermittent claudication; ischaemic stroke; inflammatory bowel disease; macular degeneration; malaria; methanol-induced toxicity; meningitis (aseptic and tuberculous); motor neuron disease; multiple sclerosis; multiple system atrophy; myocardial ischaemia; neoplasia; Parkinson's disease; peri-natal asphyxia; Pick's disease; progressive supra-nuclear palsy; radiotherapy-induced organ damage; restenosis after angioplasty; retinopathy; senile dementia; schizophrenia; sepsis; septic shock; spongiform encephalopathies; subharrachnoid haemorrhage/cerebral vasospasm; subdural haematoma; surgical trauma, including neurosurgery; thalassemia; transient ischaemic attack (TIA); traumatic brain injury (TBI); traumatic spinal injury; transplantation; vascular dementia; viral meningitis; and viral encephalitis.

[0092] Additionally, compounds of the present invention may also be used to potentiate the effects of other treatments,

for example to potentiate the neuroprotective effects of brain derived nerve growth factor.

**[0093]** The invention is particularly directed to conditions which induce oxidative damage of the central nervous system, including acute and chronic neurological disorders such as traumatic brain injury, spinal cord injury, cerebral ischaemia, stroke (ischaemic and haemorrhagic), subarachnoid haemorrhage/cerebral vasospasm, cerebral tumour, Alzheimer's disease, Huntington's disease, Parkinson's disease, Friedrich's ataxia, motor neuron disease and multiple sclerosis.

**[0094]** The invention further provides a method of treating a condition associated with oxidative stress, particularly oxidative damage of the central nervous system, comprising administering to a patient in need of such treatment an effective dose of a compound of the present invention.

**[0095]** The invention further provides a pharmaceutical composition comprising a compound of the present invention in combination with a pharmaceutically acceptable carrier or excipient and a method of making such a composition comprising combining a compound of the present invention with a pharmaceutically acceptable carrier or excipient.

**[0096]** Compounds of the present invention may be administered in a form suitable for oral use, for example a tablet, capsule, granule, powder, aqueous or oily solution, suspension or emulsion; for topical use including transmucosal and transdermal use, for example a cream, ointment, gel, aqueous or oil solution or suspension, salve, patch or plaster; for nasal use, for example a snuff, nasal spray or nasal drops; for vaginal or rectal use, for example a suppository; for administration by inhalation, for example a finely divided powder or a liquid aerosol; for sub-lingual or buccal use, for example a tablet or capsule; or for parenteral use (including intravenous, subcutaneous, intramuscular, intravascular, intrathecal or infusion), for example a sterile aqueous or oil solution or suspension. In general the above compositions may be prepared in a conventional manner using conventional excipients, using standard techniques well known to those skilled in the art of pharmacy. Preferably, the compound is administered orally for chronic disorders such as Alzheimer's and Parkinson's disease, and intravenously for acute disorders such as stroke and TBI.

**[0097]** For oral administration, the compounds of the invention will generally be provided in the form of tablets or capsules or as an aqueous solution or suspension.

**[0098]** Tablets for oral use may include the active ingredient mixed with pharmaceutically acceptable excipients such as inert diluents, disintegrating agents, binding agents, lubricating agents, sweetening agents, flavouring agents, colouring agents and preservatives. Suitable inert diluents include sodium and calcium carbonate, sodium and calcium phosphate, cyclodextrin, and lactose, while corn starch and alginic acid are suitable disintegrating agents. Binding agents may include starch and gelatin, while the lubricating agent, if present, will generally be magnesium stearate, stearic acid or talc. If desired, the tablets may be coated with a material such as glyceryl monostearate or glyceryl distearate, to delay absorption in the gastrointestinal tract.

**[0099]** Capsules for oral use include hard gelatin capsules in which the active ingredient is mixed with a solid diluent, and soft gelatin capsules wherein the active ingredient is mixed with water or an oil such as peanut oil, liquid paraffin or olive oil.

For intramuscular, intraperitoneal, subcutaneous and intravenous use, the compounds of the invention will generally be provided in sterile aqueous solutions or suspensions, buffered to an appropriate pH and isotonicity. Suitable aqueous vehicles include Ringer's solution and isotonic sodium chloride. Aqueous suspensions according to the invention may include suspending agents such as cellulose derivatives, lipids, sodium alginate, polyvinylpyrrolidone, cyclodextrins, gum tragacanth, polyethylene glycol, propylene glycol, N,N-dimethylacetamide, cremophors, polysorbates, liposomes and wetting agents such as lecithin. Suitable preservatives for aqueous suspensions include ethyl and n-propyl p-hydroxybenzoate.

**[0100]** It will be appreciated that the dosage levels used may vary over quite a wide range depending upon the compound used, the severity of the symptoms exhibited by the patient and the patient's body weight.

**[0101]** The invention will now be described in detail with reference to the following examples and figure. It will be appreciated that the invention is described by way of example only and modification of detail may be made without departing from the scope of the invention.

**[0102]** Figure 1 shows the effect of a compound of the invention on intracellular oxidation of dichlorodihydrofluorescein (DCFH) to dichlorofluorescein (DCF). IAA-stimulated fluorescence values are given as a function of concentration of the test compound.

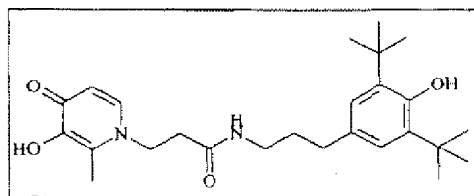
**[0103]** Figure 2 shows the *in vivo* activity of a compound of the present invention in the malonic acid lesion model of oxidative stress.

## EXPERIMENTAL

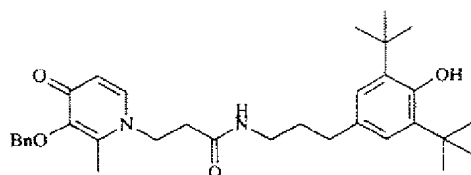
## Synthetic Examples

## Example 1

[0104] 3-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-N-(3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propyl)propanamide

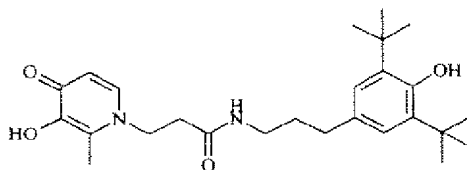


[0105] 3-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-N-(3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propyl)propanamide



Succinimidyl 3-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)propanoate [Dobbin *et al.* J. Med. Chem. (1993), 36(17), 2448-58] (0.44g, 1.1 mmol), 3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propylamine [Netherlands published patent application NL-7905000] (0.3 g, 1.1 mmol) and CH<sub>2</sub>Cl<sub>2</sub> (9.0 mL) were stirred at room temperature for 20 h, washed with 2.0-M NaOH, dried (Na<sub>2</sub>SO<sub>4</sub>), concentrated *in vacuo* and purified by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-MeOH (93:7)] to give the *product* (0.59 g, 97 %) as a clear colourless oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 3284, 2953, 1656, 1626, 1558, 1515, 1435, 1252, and 1031; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.41 (18H, s), 1.79 (2H, pent, J 7.5 Hz), 2.13 (3H, s), 2.50-2.56 (4H, m), 3.23-3.28 (2H, m), 4.11 (2H, t, J 7.0 Hz), 5.04 (1H, br s), 5.12 (2H, s), 6.33 (1H, d, J 7.5 Hz), 6.95 (2H, s), 7.10 (1H, brs), and 7.25-7.39 (6H, m).

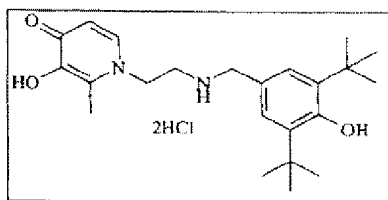
[0106] 3-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-N-(3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propyl)propanamide



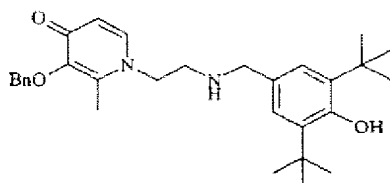
3-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-N-(3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propyl)propanamide (0.53 g, 1.0 mmol) and 10 % Pd/C (0.3 g) in EtOH (16 mL) was stirred under a H<sub>2</sub> atmosphere for 20 h. The mixture was filtered through Celite®, concentrated *in vacuo*, and purified by chromatography [Sephadex® LH-20; CH<sub>2</sub>Cl<sub>2</sub>-MeOH (80:20)] to give the *title compound* (0.35 g, 80 %) as an orange solid: mp 89 °C (decolourises at 79 °C); IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3268, 3072, 2923, 2854, 1650, 1626, 1567, 1506, 1463, 1435, 1384, 1337, 1250 and 826; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.42 (18H, s), 1.72-1.85 (2H, m), 2.39 (3H, s), 2.50-2.61 (4H, m), 3.22-3.32 (2H, m), 3.6-4.2 (2H, m), 4.19-4.30 (2H, m), 6.25-6.38 (1H, m), 6.94 (2H, s), and 7.3-7.45 (1H, m).

## Example 2

[0107] 1-[2-(3,5-Di-*tert*-butyl-4-hydroxybenzylamino)ethyl]-3-hydroxy-2-methyl-4(1*H*)-pyridinone dihydrochloride

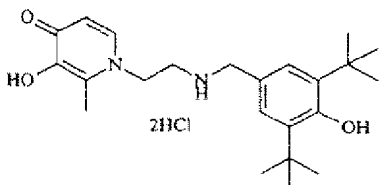


[0108] 3-Benzyloxy-1-[2-(3,5-di-*tert*-butyl-4-hydroxybenzylamino)ethyl]-2-methyl-4(1*H*)-pyridinone



A solution of 3,5-di-*tert*-butyl-4-hydroxybenzaldehyde (0.63 g, 2.7 mmol) and 1-(2-aminoethyl)-3-benzyloxy-2-methyl-4(1*H*)-pyridinone [Feng *et al.* J. Med. Chem. (1993), 36(19), 2822-7] (1.0 g, 2.7 mmol) in MeOH (14 mL) was stirred at room temperature for 5 min. NaCNBH<sub>4</sub> (0.17 g, 2.8 mmol) was added and the resulting mixture was stirred for 24 h. Saturated NaHCO<sub>3</sub> was added and the mixture was extracted with CH<sub>2</sub>Cl<sub>2</sub> (x 3). The combined organic extracts were washed with brine, dried (MgSO<sub>4</sub>), concentrated *in vacuo* and purified by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-MeOH (95:5)] to give the product (0.16 g, 13 %) as a solid foam: IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3631, 2922, 2855, 1626, 1563, 1462, 1378, 1250, 1217, 1158 and 1120; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.43 (18H, s), 2.02 (3H, s), 2.88 (2H, t, *J* 6.5 Hz), 3.65 (2H, s), 3.83 (2H, t, *J* 6.5 Hz), 5.18 (1H, s), 5.22 (2H, s), 6.40 (1H, d, *J* 7.5 Hz), 7.06 (2H, s), 7.22-7.32 (5H, m), and 7.37-7.43 (2H, m).

[0109] 1-[2-(3,5-Di-*tert*-butyl-4-hydroxybenzylamino)ethyl]-3-hydroxy-2-methyl-4(1*H*)-pyridinone dihydrochloride

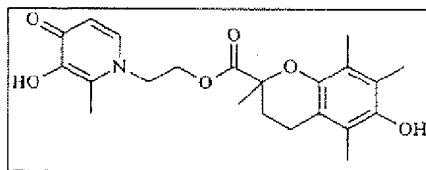


3-Benzyloxy-1-[2-(3,5-di-*tert*-butyl-4-hydroxybenzylamino)ethyl]-2-methyl-4(1*H*)-pyridinone (0.11 g, 0.24 mmol) and 10 % Pd/C (0.12 g) in EtOH (5 mL) was stirred under a H<sub>2</sub> atmosphere for 40 min. The mixture was filtered through Celite®, concentrated *in vacuo*, taken up in EtOAc:IPA and treated dropwise with 1.0-M HCl in Et<sub>2</sub>O (0.48 mL).

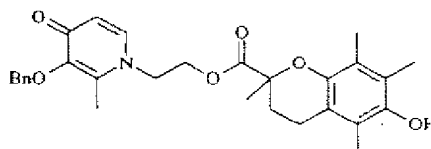
[0110] The acidic solution was concentrated *in vacuo*, taken up in CH<sub>2</sub>Cl<sub>2</sub> and triturated with Et<sub>2</sub>O. Filtration to gave the title compound (0.1 g, 96 %) as a hygroscopic off white solid: mp solid at 78 °C, appeared to foam between 78 and 100 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3632, 2921, 1633, 1509, 1461, 1377, 1344, 1240, 1217 and 1162; NMR  $\delta_{\text{H}}$  (400 MHz, DMSO-*d*<sub>6</sub>) 1.39 (18H, s), 2.56 (3H, s), 3.35-3.46 (2H, m), 3.98-4.05 (2H, m), 4.77 (2H, t, *J* 6.5 Hz), 7.28 (1H, d, *J* 7.0 Hz), 7.33 (2H, s), 8.32 (1H, d, *J* 7.0 Hz), and 9.7-9.8 (2H, m); *m/z* (ES<sup>+</sup>) 387 (78 %), 169 (100).

## Example 3

[0111] 2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2*H*-benzopyran-2-carboxylate

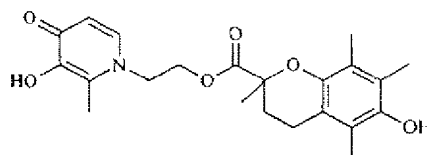


**[0112]** 2-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxylate



A solution of 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxylic acid [Trolox®] (0.50 g, 2.0 mmol), 3-benzyloxy-1-(2-hydroxyethyl)-2-methyl-4(1H)-pyridinone [Dobbin *et al.* J. Med. Chem. (1993), 36(17), 2448-58] (0.52 g, 2.0 mmol), 1-ethyl-3-[3-(dimethylamino)propyl]carbodiimide hydrochloride (0.38 g, 2.0 mmol) and DMAP (0.24 g, 2.0 mmol) in THF (20 mL) was stirred at room temperature for 17 h. The reaction mixture was concentrated *in vacuo* and the residue dissolved in EtOAc, washed with H<sub>2</sub>O (20 mL), dried (MgSO<sub>4</sub>), concentrated again *in vacuo* and purified by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-MeOH (95:5)] to give the product (0.72 g, 73 %) as a colourless foam: mp softens over 76-80 °C; IR  $\nu_{\max}$  (CH<sub>2</sub>Cl<sub>2</sub>)/cm<sup>-1</sup> 3053, 2929, 1749, 1627, 1563, 1456, 1263, 1104 and 702; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.58 (3H, s), 1.63-1.85 (1H, m), 2.06 (6H, s), 2.14 (3H, s), 2.20 (3H, s), 2.31-2.40 (2H, m), 2.58-2.63 (1H, m), 3.99-4.01 (2H, m), 4.12-4.16 (1H, m), 4.32-4.35 (1H, m), 5.17 (2H, d, *J* 3.5 Hz) and 6.83 (1H, d, *J* 7.5 Hz); Anal. Calcd. for C<sub>29</sub>H<sub>33</sub>NO<sub>6</sub> · 0.5 H<sub>2</sub>O: C, 69.58; H, 6.85; N, 2.80. Found: C, 69.89; H, 6.74; N, 2.77.

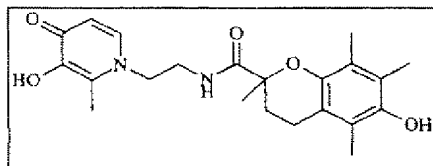
**[0113]** 2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxylate



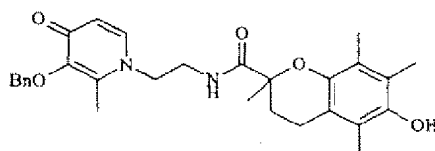
2-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxylate (0.70 g, 1.43 mmol) and 10 % Pd/C (0.15 g) in MeOH (50 mL) was stirred vigorously under a H<sub>2</sub> atmosphere for 30 min. The mixture was filtered through Celite®, and concentrated *in vacuo* to give the title compound (0.094 g, 29 %) as a pink solid: mp darkens 220 °C, melts 247-248 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3353, 2924, 1741, 1579, 1459, 1377, 1360, 1259, 1100 and 831; NMR  $\delta_{\text{H}}$  (400 MHz, DMSO-*d*<sub>6</sub>) 1.43 (3H, s), 1.73-1.74 (1H, m), 1.91 (3H, s), 1.98 (3H, s), 2.03 (3H, s), 2.17-2.25 (1H, m), 2.25 (3H, s), 2.43-2.53 (1H, m), 2.48 (3H, s), 4.18-4.21 (2H, m), 4.22-4.29 (2H, m), 6.03 (1H, d, *J* 7.8 Hz) and 7.35 (1H, d, *J* 7.7 Hz); *m/z* (ES<sup>+</sup>) 389 (100 %).

#### Example 4

**[0114]** N-(2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide

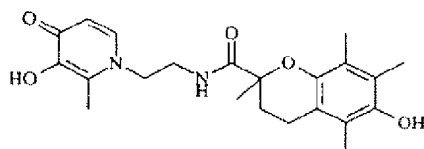


**[0115]** *N*-(2-(3-Benzoyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide



A solution of 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxylic acid [Trolox®] (2.0 g, 7.9 mmol), 1-(2-aminoethyl)-3-benzoyloxy-2-methyl-4(1H)-pyridinone [Feng *et al.* J. Med. Chem. (1993), 36(19), 2822-7] (2.05 g, 7.9 mmol), 1-ethyl-3-[3-(dimethylamino)propyl]carbodiimide hydrochloride (1.53g, 7.9 mmol) and DMAP (0.98 g, 7.9 mmol) in THF (50 mL) was stirred at room temperature for 17 h. H<sub>2</sub>O (20 mL) was added, the mixture concentrated *in vacuo* and the residue extracted with CH<sub>2</sub>Cl<sub>2</sub> (2 x 20 mL). The combined extracts were dried (MgSO<sub>4</sub>), concentrated *in vacuo* and the residue purified by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-MeOH (95:5)] to give the *product* (0.66 g, 17 %) as a colourless foam: mp softens over 110-116 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 2924, 1666, 1625, 1460, 1377, 1253, and 734; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.51 (3H, s), 1.76-1.85 (1H, m), 2.09 (3H, s), 2.10 (3H, s), 2.11 (3H, s), 2.16 (3H, s), 2.37-2.47 (1H, m), 2.58-2.66 (1H, m), 3.23-3.29 (1H, m), 3.61-3.66 (1H, m), 3.85-3.96 (2H, m), 5.15 (2H, s), 6.29 (1H, d, J 7.6 Hz), 6.64-6.65 (1H, m), 6.86 (1H, d, J 7.5 Hz) and 7.30-7.37 (5H, m); Anal. Calcd. for C<sub>29</sub>H<sub>34</sub>N<sub>2</sub>O<sub>5</sub> · H<sub>2</sub>O: C, 68.48; H, 7.13; N, 5.51. Found: C, 68.04; H, 6.91; N, 4.77.

**[0116]** *N*-(2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide

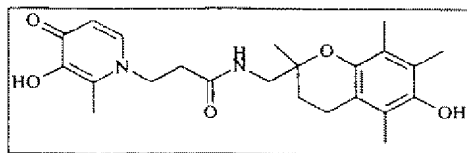


This was prepared from *N*-(2-(3-benzoyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide according to the method described in Example 1 to produce the *title compound* (0.40 g, 77 %) as a colourless foam: mp 114-115 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3342, 2924, 1730, 1508, 1460, 1255 and 826; NMR  $\delta_{\text{H}}$  (400 MHz, DMSO-*d*<sub>6</sub>) 1.29 (3H, s), 1.67-1.73 (1H, m), 1.99 (3H, s), 2.07 (3H, s), 2.25 (3H, s), 2.29-2.49 (1H, m), 2.49-2.60 (1H, m), 3.35-3.41 (2H, m), 3.93-4.03 (2H, m), 5.95 (1H, d, J 7.1 Hz), 7.15 (1H, d, J 7.7 Hz) and 7.59 (1H, t, J 6.0 Hz).

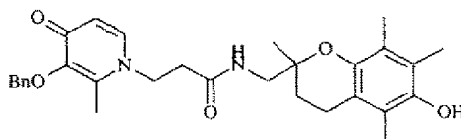
## Example 5

3-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-N-(3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylpropanamide

[0117]

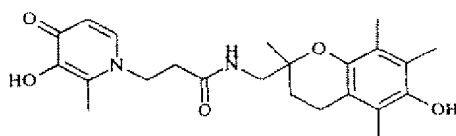


[0118] 3-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-N-(3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylpropanamide



This was prepared from 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-methylamine [EP 183869] and 3-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)propanoic acid [Dobbin *et al.* *J. Med. Chem.* (1993), 36(17), 2448-58] according to the method described in Example 4 to give the *product* (0.91 g, 39 %) as a colourless foam: mp softens over 107-112 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3264, 2926, 2854, 1625, 1556, 1460, 1378, 1254 and 734; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.15 (3H, s), 1.69-1.73 (2H, m), 2.05 (3H, s), 2.07 (3H, s), 2.11 (3H, s), 2.53-2.63 (4H, m), 3.36-3.49 (2H, m), 4.12 (2H, t, *J* 6.6 Hz), 5.10 (2H, d, *J* 1.9 Hz), 6.33 (1H, d, *J* 7.45 Hz) and 7.24-7.34 (6H, m).

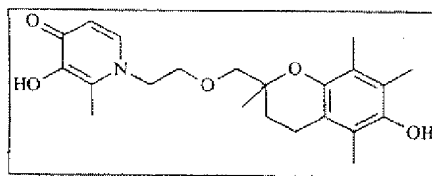
[0119] 3-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-N-(3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylpropanamide



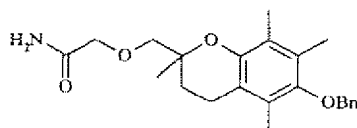
This was prepared from 3-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-N-(3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylpropanamide according to the method described in Example 1 to produce the *title compound* (0.90 g, 85 %) as an off-white solid: mp 234-235 °C (dec); IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3387, 3214, 3067, 2924, 2854, 1657, 1628, 1568, 1509, 1463, 1254 and 821; NMR  $\delta_{\text{H}}$  (400 MHz, DMSO-*d*<sub>6</sub>) 1.04 (3H, s), 1.57-1.61 (2H, m), 1.96 (3H, s), 1.99 (3H, s), 2.02 (3H, s), 2.29 (3H, s), 2.40-2.56 (2H, m), 2.59 (2H, t, *J* 6.6 Hz), 3.13-3.26 (2H, m), 4.14 (2H, t, *J* 6.6 Hz), 6.04 (1H, d, *J* 7.0 Hz), 7.45 (1H, d, *J* 7.5 Hz) and 7.99 (1H, t, *J* 6.0 Hz).

## Example 6

[0120] 3-Hydroxy-1-[2-(6-hydroxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]ethyl]-2-methyl-4(1H)-pyridinone

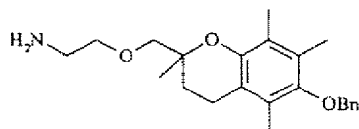


**[0121]** 2-[(6-Benzyloxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]acetamide



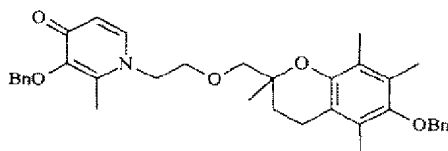
A solution of 6-benzyloxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-methanol [Suarna *et al.* Aust. J. Chem. (1997), 50(12), 1129-1135] (3.1 g, 9.5 mmol) in DMF (30 mL) was added dropwise to a suspension of NaH (60 % in oil, 5.7 g, 143 mmol) in DMF (60 mL) at -30 °C. The mixture was stirred for 1 h at -30 °C, then a solution of iodoacetamide (1.9 g, 10.5 mmol) in DMF (20 mL) was added dropwise. The reaction mixture was then warmed to room temperature and stirred for 20 h. Water (5 mL) was added dropwise to the stirred mixture, then the reaction was concentrated *in vacuo*. The residue was extracted with EtOAc, and the organic phase was washed with brine, dried (MgSO<sub>4</sub>), concentrated *in vacuo* and purified by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-EtOAc (80:20)] to give the *product* (1.7 g, 45 %) as a white solid: mp 100-101 °C; IR  $\nu_{\max}$  (CH<sub>2</sub>Cl<sub>2</sub>)/cm<sup>-1</sup> 3473, 2928, 1690, 1455, 1413, 1373, 1256, 1119, 1088 and 699; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.27 (3H, s), 1.72-1.81 (1H, m), 1.97-2.08 (1H, m), 2.09 (3H, s), 2.18 (3H, s), 2.22 (3H, s), 2.65 (2H, t, *J* 7.0 Hz), 3.61 (2H, q<sub>AB</sub>, *J* 10.0 Hz), 4.05 (2H, q<sub>AB</sub>, *J* 16.0 Hz), 4.69 (2H, s), 5.66-5.77 (1H, m), 6.75-6.85 (1H, m), and 7.30-7.52 (5H, m); Anal. Calcd. for C<sub>23</sub>H<sub>29</sub>NO<sub>4</sub>: C, 72.04; H, 7.62; N, 3.65. Found: C, 71.60; H, 7.61; N, 3.56; *m/z* (ES<sup>+</sup>) 384 (38 %), 293 (100).

**[0122]** 2-[(6-Benzyloxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]ethylamine



A solution 2-[(6-benzyloxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]acetamide (1.6 g, 4.1 mmol) in THF (50 mL) under argon was treated dropwise with BH<sub>3</sub>·Me<sub>2</sub>S (0.8 mL, 8.2 mmol). The mixture was stirred and heated at reflux for 21 h. The reaction mixture was cooled, then conc. HCl (2.7 mL) was added dropwise. The mixture was heated at reflux for 15 min, re-cooled and then concentrated *in vacuo*. The residue was adjusted to pH 14 with 2-M NaOH, then extracted with EtOAc, and the organic phase was washed with brine, dried (MgSO<sub>4</sub>), concentrated *in vacuo* and purified by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-MeOH gradient (95:5 to 80:20)] to give the *product* (1.2 g, 78 %) as a colourless oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 3376, 2928, 2864, 1455, 1413, 1372, 1257, 1110, 1089, 1062, 1018 and 698; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.30 (3H, s), 1.73-1.82 (1H, m), 1.9-2.05 (1H, m), 2.10 (3H, s), 2.17 (3H, s), 2.22 (3H, s), 2.61 (2H, t, *J* 7.0 Hz), 2.75-3.0 (2H, m), 3.49 (2H, q<sub>AB</sub>, *J* 10.0 Hz), 3.5-3.62 (2H, m), 4.69 (2H, s), 7.43-7.42 (3H, m), and 7.5 (2H, d, *J* 7.0 Hz); Anal. Calcd. for C<sub>23</sub>H<sub>31</sub>NO<sub>3</sub>·0.25H<sub>2</sub>O: C, 73.86; H, 8.49; N, 3.75. Found: C, 73.97; H, 8.40; N, 3.75.

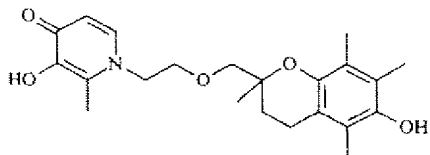
**[0123]** 3-Benzyloxy-1-[2-(6-benzyloxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]ethyl]-2-methyl-4(1H)-pyridinone





2-[(6-Benzyloxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]ethylamine (1.0 g, 2.7 mmol), 3-benzyloxy-2-methyl-4-pyrone [Dobbin *et al.* J. Med. Chem. (1993), 36(17), 2448-58] (0.9 g, 4.1 mmol) and 5.0-M NaOH (1.1 mL, 5.5 mmol) in EtOH (9 mL) and water (5 mL) were refluxed for 5 h. The reaction was cooled, adjusted to pH 3-4 with 1.0-M HCl, concentrated *in vacuo*, extracted with CH<sub>2</sub>Cl<sub>2</sub>, dried (MgSO<sub>4</sub>), concentrated *in vacuo* and purified by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-MeOH (96.5:3.5)] to give the *product* (0.64 g, 41 %) as a brown oily foam: IR  $\nu_{\max}$  (CH<sub>2</sub>Cl<sub>2</sub>)/cm<sup>-1</sup> 2926, 2867, 1628, 1574, 1455, 1254, 1111, 1089 and 701; NMR  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 1.19 (3H, s), 1.63-1.73 (1H, m), 1.8-1.9 (1H, m), 2.06 (3H, s), 2.12 (3H, s), 2.16 (3H, s), 2.21 (3H, s), 2.47-2.54 (2H, m), 3.41 (2H, q<sub>AB</sub>, *J* 10.0 Hz), 3.62-3.75 (2H, m), 3.88-4.0 (2H, m), 4.67 (2H, s), 5.2 (2H, s), 6.40 (1H, d, *J* 7.5 Hz), 7.2-7.44 (9H, m), and 7.49 (2H, d, *J* 7.5 Hz).

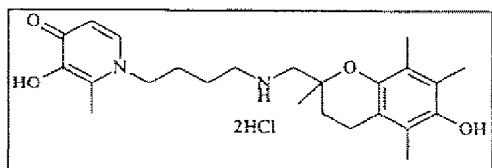
**[0124]** 3-Hydroxy-1-[2-(6-hydroxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]ethyl]-2-methyl-4(1H)-pyridinone



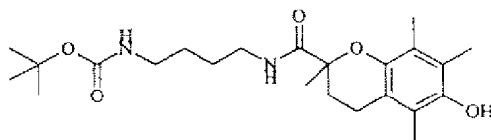
This was prepared from 3-benzyloxy-1-[2-(6-benzyloxy-3,4-dihydro-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methoxy]ethyl]-2-methyl-4(1H)-pyridinone according to the method described in Example 1, to produce the *title compound* (0.42 g, 100 %) as a white solid: mp 70-73 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3190, 2923, 2855, 1627, 1575, 1509, 1463, 1377, 1350, 1277, 1258, 1208, 1135, 1117, 1103 and 1089; NMR  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 1.18 (3H, s), 1.60-1.70 (1H, m), 1.77-1.87 (1H, m), 2.05 (3H, s), 2.10 (3H, s), 2.16 (3H, s), 2.39 (3H, s), 2.45-2.63 (2H, m), 3.42 (2H, q<sub>AB</sub>, *J* 10.0 Hz), 3.70-3.85 (2H, m), 3.98-4.2 (2H, m), 3.65-4.2 (2H, br m), 6.36 (1H, d, *J* 7.5 Hz), and 7.27 (1H, d, *J* 7.5 Hz); NMR  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) 11.36, 11.87, 12.16, 12.29, 20.20, 21.93, 28.64, 53.38, 70.42, 74.61, 77.03, 110.83, 117.15, 118.93, 121.61, 122.28, 128.23, 137.67, 144.93, 145.04, 145.94, and 169.48; Anal. Calcd. for C<sub>22</sub>H<sub>29</sub>NO<sub>5</sub> · 0.5H<sub>2</sub>O: C, 66.65; H, 7.63; N, 3.53. Found: C, 66.88; H, 7.65; N, 3.44; *m/z* (ES+) 388 (100 %), 389 (35).

#### Example 7

**[0125]** 1-[4-(3,4-Dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylamino]butyl]-3-hydroxy-2-methyl-4(1H)-pyridinone dihydrochloride



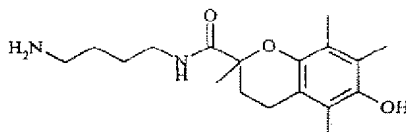
**[0126]** N-(4-(tert-Butoxycarbonylamino)butyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide



A solution of 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxylic acid [Trolox®] (5.0 g, 20 mmol), 1-ethyl-3-[3-(dimethylamino)propyl]carbodiimide hydrochloride (4.0 g, 21 mmol), hydroxybenzotriazole (2.8 g, 21 mmol), diisopropylethylamine (6.7 mL, 40 mmol) and DMF (120 mL) was stirred at room temperature under argon for 40 min. N-(tert-butoxycarbonyl)-1,4-diaminobutane (3.8 g, 20 mmol) was added as a solid. The reaction mixture was

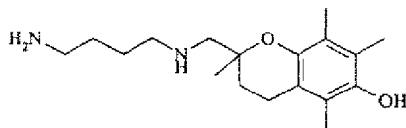
stirred under argon for 20 h. The reaction was concentrated *in vacuo*, then taken up in EtOAc, washed with water (x 2), 1.0-M HCl (x 2), brine, saturated NaHCO<sub>3</sub> (x 2), brine, dried (MgSO<sub>4</sub>), and concentrated *in vacuo*. Purification by chromatography [SiO<sub>2</sub>; CH<sub>2</sub>Cl<sub>2</sub>-MeOH (95:5)] gave the *product* (6.1 g, 72 %) as a white oily foam: mp 45 °C; IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 3429, 3353, 2978, 2932, 2869, 1667, 1526, 1454, 1367, 1255, 1172 and 1090; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.04-1.18 (2H, m), 1.25-1.39 (2H, m), 1.44 (9H, s), 1.53 (3H, s), 1.8-1.9 (1H, m), 2.09 (3H, s), 2.18 (3H, s), 2.19 (3H, s), 2.35-2.48 (1H, m), 2.49-2.65 (2H, m), 2.84-2.99 (2H, m), 3.00-3.13 (1H, m), 3.26-3.30 (1H, m), 4.42-4.52 (1H, m), and 6.3-6.4 (1H, m).

**[0127]** *N*-(4-Aminobutyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide



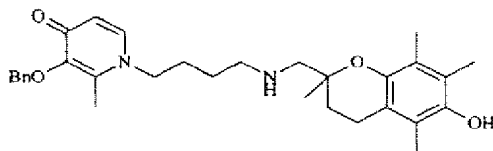
A solution of *N*-(4-(*tert*-butoxycarbonylamino)butyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide (3.4 g, 8.0 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (50 mL) was treated dropwise with trifluoroacetic acid (25 mL) and stirred at room temperature for 30 min. The reaction was concentrated *in vacuo*, then taken up in CH<sub>2</sub>Cl<sub>2</sub> and concentrated again. This process was repeated twice more before the residue was basified to pH 11 with 2.0-M NaOH. The basic residue was extracted with EtOAc (x 3), and the combined organic phases were washed with brine, dried (MgSO<sub>4</sub>), and concentrated *in vacuo* to give the *product* (1.5 g, 60 %), essentially pure, as an oil which eventually crystallized on standing: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 3428, 3305, 2933, 2865, 1662, 1530, 1453, 1373, 1258 and 1089; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.03-1.15 (2H, m), 1.28-1.47 (3H, m), 1.53 (3H, s), 1.78-1.90 (1H, m), 2.08 (3H, s), 2.18 (6H, s), 2.35-2.45 (1H, m), 2.45-2.65 (3H, m), 3.0-3.1 (1H, m), 3.3-3.37 (1H, m), 3.47 (3H, m), and 6.4 (1H, br t, *J* 5.5 Hz).

**[0128]** *N*-(4-Aminobutyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-methylamine



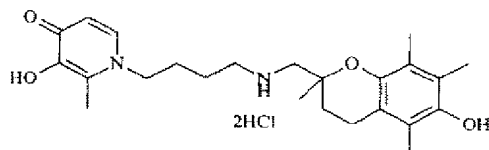
A solution of *N*-(4-aminobutyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxamide (1.5 g, 4.1 mmol) in THF (60 mL) under argon was treated dropwise with 1.0-M LiAlH<sub>4</sub> in THF (30 mL). The mixture was stirred and heated at reflux for 72 h. The reaction mixture was cooled then quenched by adding water (1.14 mL), 1.0-M NaOH (3.4 mL) and water (1.14 mL) sequentially dropwise. The mixture was stirred for 2 h, filtered and then concentrated *in vacuo* to give the crude *product* (0.8 g, approx. 57 %) as an oil. This was used in the next reaction without further purification: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 3357, 2932, 2864, 1162, 1528, 1456, 1377, 1259, 1089 and 1061.

**[0129]** 3-Benzyloxy-1-[4-(3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylamino]butyl]-2-methyl-4(1H)-pyridinone



This was prepared from *N*-(4-aminobutyl)-3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-methylamine according to the method described in Example 6, to produce the *product* (0.29 g, 21 %) as a sticky brown foam: NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.26 (3H, s), 1.39-1.52 (2H, m), 1.6-1.8 (3H, m), 1.90-2.04 (1H, m), 2.06 (3H, s), 2.07 (3H, s), 2.12 (3H, s), 2.16 (3H, s), 2.58-2.78 (6H, m), 3.74 (2H, t, *J* 7.5 Hz), 5.2 (2H, s), 6.4 (1H, d, *J* 7.5 Hz), 7.15 (1H, d, *J* 7.5 Hz), and 7.23-7.42 (6H, m); *m/z* (ES<sup>+</sup>) 507 (42 %), 506 (100).

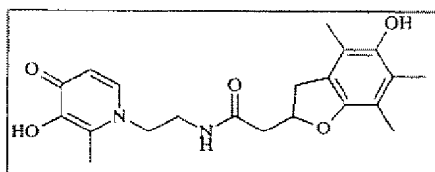
**[0130]** 1-[4-(3,4-Dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylamino]butyl]-3-hydroxy-2-methyl-4(1H)-pyridinone dihydrochloride



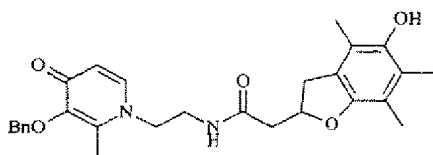
This was prepared from 3-benzyloxy-1-[4-(3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2H-benzopyran-2-yl)methylamino]butyl]-2-methyl-4(1*H*)-pyridinone according to the method described in Example 2, to produce the *title compound* (0.11 g, 96 %) as a hygroscopic buff coloured solid: mp darkens and decomposes, then appears to melt above 150 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3347, 2934, 1632, 1508, 1461, 1377, 1341, 1258, 1168, 1088 and 1033; NMR  $\delta_H$  (400 MHz, DMSO-*d*<sub>6</sub>) 1.24 (3H, s), 1.62-1.95 (6H, m), 2.01 (3H, s), 2.03 (3H, s), 2.06 (3H, s), 2.55 (3H, s), 2.5-3.2 (6H, m), 4.36 (2H, br t, *J* 6.5 Hz), 7.30 (1H, d, *J* 7.0 Hz), 8.27 (1H, d, *J* 7.0 Hz), and 8.8-9.0 (2H, m); *m/z* (ES<sup>+</sup>) 415 (100 %), 290 (2B). Anal. Calcd. for C<sub>24</sub>H<sub>34</sub>N<sub>2</sub>O<sub>4</sub> · 2HCl · 3H<sub>2</sub>O: C, 53.23; H, 7.82; N, 5.17. Found: C, 52.82; H, 7.78; N, 4.80.

### Example 8

**[0131]** N-(2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl)-2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetamide

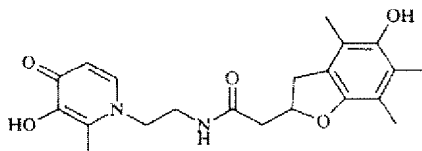


**[0132]** N-(2-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl)-2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetamide



This was prepared from 2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-ethanoic acid [Ceccarelli *et al.* J. Heterocycl. Chem. (1993), 30(3), 679-90] and 1-(2-aminoethyl)-3-benzyloxy-2-methyl-4(1*H*)-pyridinone [Feng *et al.* J. Med. Chem. (1993), 36(19), 2822-7] according to the method described in Example 4 to give the *product* (0.19 g, 17 %) as a pale-yellow foam: mp softens over 104-105 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3245, 2922, 1625, 1552, 1462, 1378, 1249, 1075 and 752; NMR  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 1.99 (3H, s), 2.05 (3H, s), 2.18 (3H, s), 2.60-2.81 (4H, m), 3.07-3.13 (1H, m), 3.41-3.42 (2H, m), 3.97 (2H, m), 4.99 (2H, s), 4.88-5.16 (1H, m), 6.39 (1H, d, *J* 7.0 Hz), 7.24-7.39 (6H, m), and 8.37 (1H, m).

**[0133]** N-(2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl)-2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetamide

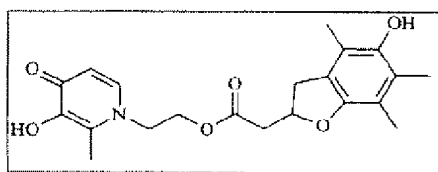


This was prepared from N-(2-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl)-2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetamide according to the method described in Example 1 to give the *title compound*

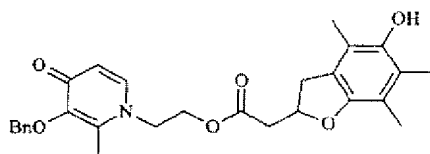
(0.35 g, 94 %) as a pink foam: mp darkens 96 °C, melts 130-131 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 3253, 2924, 1628, 1563, 1462, 1378, 1240 and 1075; NMR  $\delta_{\text{H}}$  (400 MHz, DMSO-*d*<sub>6</sub>) 2.29 (3H, s), 3.36 (1H, dd, *J* 14.7, 6.5), 2.55 (1H, dd, *J* 14.4, 6.3 Hz), 2.69 (1H, dd, *J* 16.1, 7.5 Hz), 3.12 (1H, dd, *J* 15.7, 8.6 Hz), 3.28-3.40 (2H, m), 3.95-3.98 (2H, m), 4.86-4.93 (1H, m), 6.06 (1H, d, *J* 6.9 Hz), 7.42 (1H, d, *J* 7.3 Hz) and 8.14-8.16 (1H, m).

### Example 9

**[0134]** 2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl 2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetate

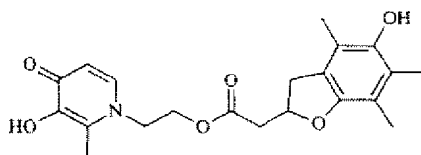


**[0135]** 2-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl 2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetate



This was prepared from 2-(2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-yl)ethanoic acid and 1-(2-hydroxyethyl)-3-benzyloxy-2-methyl-4(1*H*)-pyridinone according to the method described in Example 3 to give the *product* (1.56 g, 52 %) as a light brown foam: mp softens and darkens over 75-80 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 2924, 1740, 1626, 1562, 1462, 1378, 1241 and 723; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 2.06 (3H, s), 2.12 (6H, s), 2.18 (3H, s), 2.64 (1H, dd, *J* 15.9 Hz, 5.9 Hz), 2.78 (1H, dd, *J* 16.0, 7.4 Hz), 3.29 (1H, dd, *J* 14.9, 9.0 Hz), 4.14-4.17 (1H, m), 4.27-4.36 (2H, m), 5.02-5.05 (1H, m), 5.20 (2H, s), 6.72 (1H, br s) and 7.27-7.45 (6H, m).

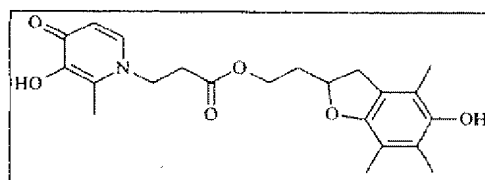
**[0136]** 2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl 2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetate



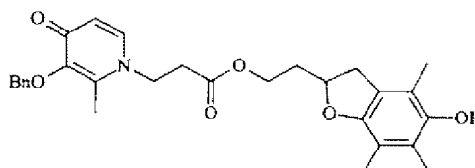
This was prepared from 2-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl 2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-acetate according to the method described in Example 1 to give the *title compound* (0.58 g, 51 %) as a pale-brown foam: IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 2924, 1739, 1626, 1572, 1461, 1241, and 826; NMR  $\delta_{\text{H}}$  (400 MHz, DMSO-*d*<sub>6</sub>) 2.01 (3H, s), 2.00 (3H, s), 1.93 (3H, s), 2.30 (3H, s), 2.69-2.73 (3H, m), 3.16 (1H, dd, *J* 15.7, 8.9 Hz), 4.16-4.25 (2H, m), 4.30-4.38 (2H, m), 4.87-4.94 (1H, pent, *J* 7.0 Hz), 6.07 (1H, d, *J* 7.4 Hz) and 7.54 (1H, d, *J* 7.2 Hz); Anal. Calcd. for C<sub>21</sub>H<sub>25</sub>NO<sub>6</sub> · 0.25 H<sub>2</sub>O: C, 64.35; H, 6.56; N, 3.57. Found: C, 64.44; H, 6.45; N, 3.42.

### Example 10

**[0137]** 2-(2,3-Dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-yl)ethyl 3-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)propanoate

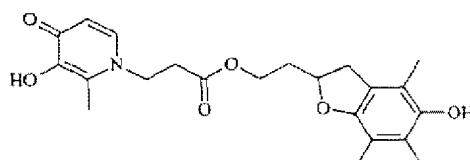


**[0138]** 2-(2,3-Dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-yl)ethyl 3-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)propanoate



This was prepared from 2-(2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-yl)ethanol and 3-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)propanoic acid according to the method described in Example 4 to give the *product* (1.2 g, 41 %) as a pale-brown foam: IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 2923, 1731, 1625, 1461, 1377, 1239 and 1073; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.93-2.03 (2H, m), 2.06 (3H, s), 2.09 (3H, s), 2.10 (3H, s), 2.11 (3H, s), 2.62 (2H, t, *J* 7.2 Hz), 2.73 (1H, dd, *J* 15.2 Hz, 7.0 Hz), 3.03-3.34 (1H, m), 4.07 (1H, t, *J* 6.9 Hz), 4.29 (2H, t, *J* 7.0 Hz), 4.59-4.83 (1H, m), 5.18 (2H, s), 6.41 (1H, d, *J* 7.5 Hz) and 7.24-7.38 (6H, m).

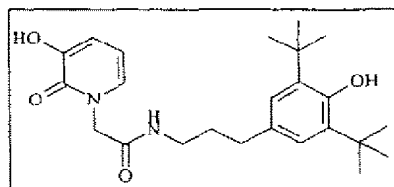
**[0139]** 2-(2,3-Dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-yl)ethyl 3-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)propanoate



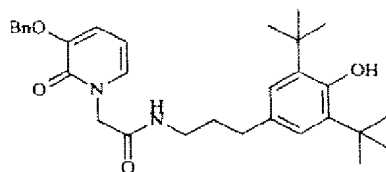
This was prepared from 2-(2,3-dihydro-5-hydroxy-4,6,7-trimethylbenzofuran-2-yl)ethyl 3-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)propanoate according to the method described in Example 1 to give the *title compound* (0.83 g, 85 %) as an off-white foam: mp softens over 65-70 °C; IR  $\nu_{\max}$  (Nujol)/cm<sup>-1</sup> 2922, 1731, 1572, 1461, 1240, 1073 and 826; NMR  $\delta_{\text{H}}$  (400 MHz, DMSO-*d*<sub>6</sub>) 1.89-1.97 (1H, m), 1.97 (3H, s), 2.02 (6H, s), 2.30 (3H, s), 2.72 (1H, dd, *J* 14.9, 6.9 Hz), 2.79 (2H, t, *J* 7.1 Hz), 3.16 (1H, dd, *J* 15.8, 9.2 Hz), 4.17-4.21 (4H, m), 4.68-4.71 (1H, m), 6.09 (1H, d, *J* 7.6 Hz) and 7.56 (1H, d, *J* 7.3 Hz).

#### Example 11

**[0140]** N-(3-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)propyl)-2-(1,2-dihydro-3-hydroxy-2-oxo-1-pyridinyl)acetamide

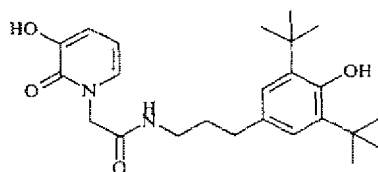


[0141] 2-(3-Benzoyloxy-1,2-dihydro-2-oxo-1-pyridinyl)-N-(3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propyl)acetamide



This is prepared from succinimidyl 3-(3-benzoyloxy-1,2-dihydro-2-oxo-1-pyridinyl)acetate [Streater *et al.* J. Med. Chem. (1990), 33(6), 1749-1755] and 3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propylamine [NL7905000] according to the method described in Example 1 to give the *product*.

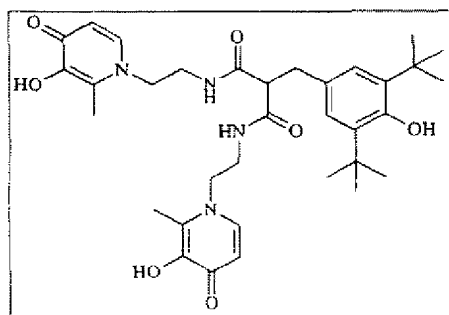
[0142] N-(3-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)propyl)-2-(1,2-dihydro-3-hydroxy-2-oxo-1-pyridinyl)acetamide



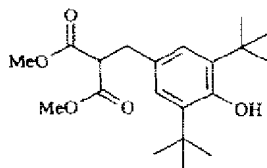
This is prepared from 2-(3-benzoyloxy-1,2-dihydro-2-oxo-1-pyridinyl)-N-(3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propyl)acetamide according to the method described in Example 1 to give the *title compound*.

#### Example 12

[0143] N,N'-Bis-(2-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl)-2-(3,5-di-*tert*-butyl-4-hydroxybenzyl)malonamide



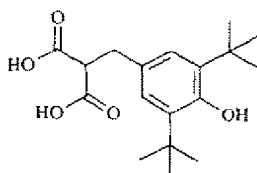
[0144] Dimethyl 2-(3, 5-di-*tert*-butyl-4-hydroxybenzyl)malonate



A suspension of hexane-washed NaH (2.91g of 60 % dispersion in mineral oil, 73 mmol) in a mixture of THF (80 mL) and DMF (30 mL) is cooled to 0 °C under Ar and treated dropwise with dimethyl malonate (7.9 mL, 69 mmol). After a further 10 min at 20 °C, a solution of 3,5-di-*tert*-butyl-4-hydroxybenzyl bromide (69 mmol) in a mixture of THF (20 mL) and DMF (20 mL) is added, and the mixture is heated under gentle reflux for 1 h. The reaction is then poured into brine,

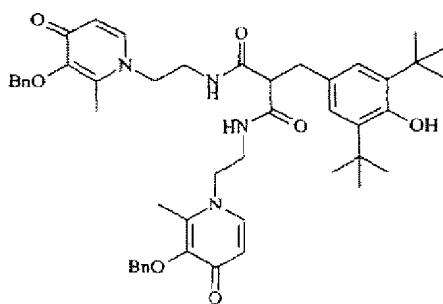
extracted with EtOAc and concentrated *in vacuo*. Kugelrohr distillation at 130 °C (20mm Hg) is used to remove unreacted dimethyl malonate. The residue is purified by chromatography [SiO<sub>2</sub>; EtOAc-Hexane] to give the product.

**[0145]** 2-(3,5-Di-*tert*-butyl-4-hydroxybenzyl)malonic acid



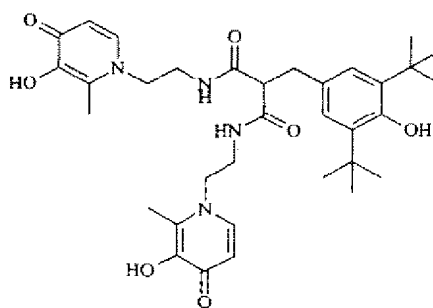
A solution of dimethyl 2-(3,5-di-*tert*-butyl-4-hydroxybenzyl)malonate (60.0 mmol) in a mixture of THF (80 mL) and water (30 mL) is treated with NaOH (130 mmol). After stirring at room temperature for 24 h the reaction is then concentrated *in vacuo*. The residue is acidified to pH 1-2, and the aqueous phase is extracted with EtOAc. The organic layer is washed with brine, dried (MgSO<sub>4</sub>), and purified by chromatography [SiO<sub>2</sub>; EtOAc-Hexane] to give the product.

**[0146]** *N,N'*-Bis-(2-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl)-2-(3,5-di-*tert*-butyl-4-hydroxybenzyl)malonamide



This is prepared from 2-(3,5-di-*tert*-butyl-4-hydroxybenzyl)malonic acid and two equivalents of 1-(2-aminoethyl)-3-benzyloxy-2-methyl-4(1*H*)-pyridinone [Feng *et al. J. Med. Chem.* (1993), 36(19), 2822-7] according to the method described in Example 4 to give the product.

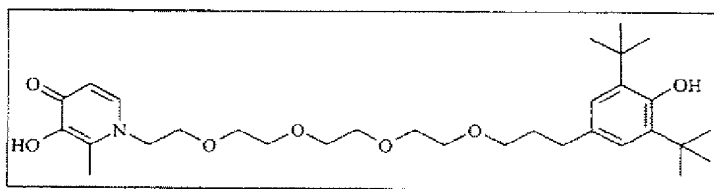
**[0147]** *N,N'*-Bis-(2-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl)-2-(3,5-di-*tert*-butyl-4-hydroxybenzyl)malonamide



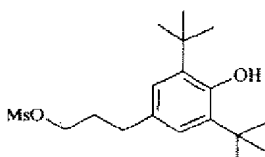
This is prepared from *N,N*-bis-(2-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl)-2-(3,5-di-*tert*-butyl-4-hydroxybenzyl)malonamide according to the method described in Example 1 to produce the title compound.

### Example 13

**[0148]** 1-(15-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)-3,6,9,12-tetraoxapentadecyl)-3-hydroxy-2-methyl-4(1*H*)-pyridinone

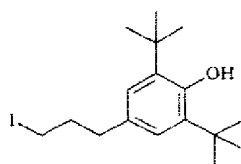


**[0149]** 3-(3,5-Di-tert-butyl-4-hydroxyphenyl)propyl methanesulphonate



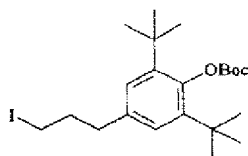
A solution of 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propanol [A. W. White and R. S. Beavers; US 4910286] (9.8 g, 37 mmol) in  $\text{CH}_2\text{Cl}_2$  (200 mL) at room temperature was treated sequentially with  $\text{Et}_3\text{N}$  (10.3 mL, 74 mmol) and a solution of methanesulphonyl chloride (2.9 mL, 37 mmol) in  $\text{CH}_2\text{Cl}_2$  (50 mL) dropwise. The resulting mixture was stirred for 0.5 h, then washed with 1.0-M HCl, followed by brine. The organic layer was then dried ( $\text{MgSO}_4$ ) and concentrated *in vacuo* to give the crude product. Trituration with  $\text{Et}_2\text{O}$  gave the *product* (7.5 g, 59 %), essentially pure as a pale yellow solid: mp 113-113.5 °C; IR  $\nu_{\text{max}}$  (Nujol)/ $\text{cm}^{-1}$  3592, 2925, 2855, 1459, 1437, 1349, 1171, 1140, 972, 942, 847 and 533; NMR  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 1.43 (18H, s), 2.01-2.08 (2H, m), 2.65 (2H, t,  $J$  7.5 Hz), 3.00 (3H, s), 4.25 (2H, t,  $J$  6.5 Hz), 5.09 (1H, s), and 7.02 (2H, s).

**[0150]** 4-(3-Iodopropyl)-2,6-di-tert-butylphenol



A solution of 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propyl methanesulphonate (7.3 g, 21 mmol) in acetone (214 mL) at room temperature was treated with NaI (6.4 g, 43 mmol) and  $\text{K}_2\text{CO}_3$  (0.3 g, 2.1 mmol). The reaction mixture was refluxed for 6.5 h, then filtered to remove the precipitate. The filtrate was reduced *in vacuo*, taken up in EtOAc and washed with water, dried ( $\text{MgSO}_4$ ), reduced *in vacuo* and then purified by chromatography [ $\text{SiO}_2$ ; Heptane-EtOAc gradient (100:0 to 95:5)] to give the *product* (7.3 g, 91 %) as a yellow solid: mp 76 °C; IR  $\nu_{\text{max}}$  (Nujol)/ $\text{cm}^{-1}$  3644, 3619, 2924, 2856, 1457, 1434, 1377, 1380, 1229, 1213, 1168, 877 and 787; NMR  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 1.43 (18H, s), 2.04-2.13 (2H, m), 2.63 (2H, t,  $J$  7.5 Hz), 3.19 (2H, t,  $J$  7.0 Hz), 5.07 (1H, s), and 6.98 (2H, s).

**[0151]** tert-Butyl 2,6-di-tert-butyl-4-(3-iodopropyl)phenyl carbonate

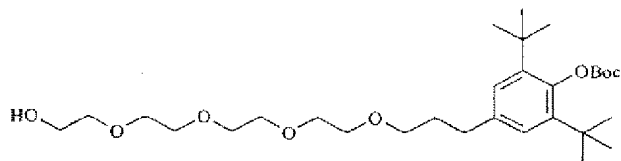


A solution of 4-(3-iodopropyl)-2,6-di-tert-butylphenol (3.0 g, 8.0 mmol), di-tert-butyl dicarbonate (2.7 g, 12.4 mmol) and 4-dimethylaminopyridine (50 mg, 0.4 mmol) in heptane (20 mL) was stirred at room temperature overnight. EtOAc was added and the resulting solution was washed with 1.0-M HCl, then brine. The organic layer was dried ( $\text{Na}_2\text{SO}_4$ ) then reduced *in vacuo* to afford the *product* (3.4 g, 89%) as a brown oil which crystallises over time. This was used in the subsequent reaction without further purification: IR  $\nu_{\text{max}}$  (liquid film)/ $\text{cm}^{-1}$  2956, 2873, 1757, 1367, 1256, 1212, 1154, 1113, 1047, 890, 782 and 733; NMR  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 1.36 (18H, s), 1.52 (9H, s), 2.09 (2H, pent,  $J$  8.0 Hz), 2.67



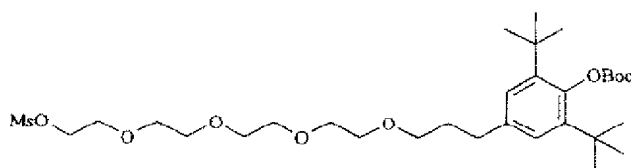
(2H, t,  $J$  8.0 Hz), 3.20 (2H, t,  $J$  8.0 Hz), 7.10 (2H, s).

*tert*-Butyl 2,6-di-*tert*-butyl-4-(15-hydroxy-4,7,10,13-tetraoxapentadecyl)phenyl carbonate



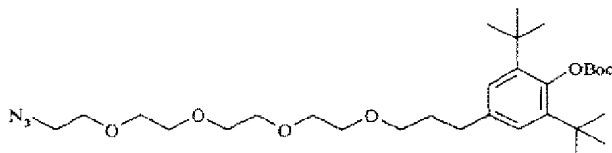
Tetraethylene glycol (3.3 g, 17.3 mmol) was added dropwise to a suspension of NaH (50 % in oil, 300 mg, 7.5 mmol) in DMF (15 mL) at 0°C. The mixture was stirred for 30 min at room temperature then a DMF (8 mL) solution of *tert*-butyl 2,6-di-*tert*-butyl-4-(3-iodopropyl)phenyl carbonate (3.3 g, 6.9 mmol) was added dropwise. The resulting solution was heated to 90°C for 1.5 h. After cooling, the reaction mixture was poured into water (50 mL) and extracted with EtOAc (2 x 25 mL). The organic layer was washed with brine (2 x 30 mL), dried (Na<sub>2</sub>SO<sub>4</sub>) then reduced *in vacuo* and purified by chromatography [SiO<sub>2</sub>; gradient EtOAc: acetone (100:0 to 85:15)] to afford the *product* (1.39 g, 37 %) as a yellow oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 3460, 2956, 2871, 1757, 1368, 1274, 1257, 1213, 1155, 1114, 891 and 783; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.36 (18H, s), 1.52 (9H, s), 1.90 (2H, pent,  $J$  8.0 Hz), 2.62 (2H, t,  $J$  8.0 Hz), 3.50 (2H, t,  $J$  8.0 Hz), 3.60-3.70 (16H, m), 7.08 (2H, s);  $m/z$  (Cl, NH<sub>3</sub>) (MNH<sub>4</sub><sup>+</sup>) 559 (100%), (MH<sup>+</sup>) 542 (10), 502 (35). Early fractions from the column contained the *elimination product* (loss of HI from starting iodide) *tert*-butyl-[2,6-di-*tert*-butyl-4-(2-propenyl)]phenylcarbonate as an orange oil (700 mg, 29%); NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.37 (18H, s), 1.55 (9H, s), 3.35 (2H, d,  $J$  6.8 Hz), 5.08 (1H, m), 5.99 (2H, m), 7.12 (2H, s);  $m/z$  (Cl, NH<sub>3</sub>) (MNH<sub>4</sub><sup>+</sup>) 364 (100%).

*tert*-Butyl 2,6-di-*tert*-butyl-4-(15-methanesulphonyl-4,7,10,13-tetraoxapentadecyl)phenyl carbonate



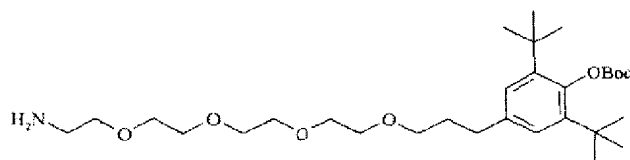
A solution of *tert*-butyl 2,6-di-*tert*-butyl-4-(15-hydroxy-4,7,10,13-tetraoxapentadecyl)phenyl carbonate (1.39 g, 2.6 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (10 mL) at room temperature was treated dropwise with Et<sub>3</sub>N (840  $\mu$ L, 6.0 mmol) then methanesulphonyl chloride (240  $\mu$ L, 3.12 mmol). The resulting mixture was stirred for 1 h, then diluted with CH<sub>2</sub>Cl<sub>2</sub> (20 mL) and washed with 1.0-M HCl, then brine. The organic layer was dried (Na<sub>2</sub>SO<sub>4</sub>) and reduced *in vacuo* to afford the *product* (1.54 g, 97 %) as an orange oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 2960, 2871, 1756, 1598, 1455, 1354, 1274, 1175, 1155, 1114 and 922; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.36 (18H, s), 1.54 (9H, s), 1.90 (2H, pent,  $J$  8.0 Hz), 2.62 (2H, t,  $J$  8.0 Hz), 3.07 (3H, s), 3.50 (2H, t,  $J$  8.0 Hz), 3.60 (2H, m), 3.66 (10H, m), 3.76 (2H, m), 4.38 (2H, m), 7.15 (2H, s).

*tert*-Butyl 2,6-di-*tert*-butyl-4-(15-azido-4,7,10,13-tetraoxapentadecyl)phenyl carbonate



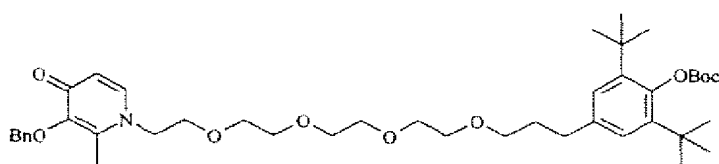
A suspension of *tert*-butyl 2,6-di-*tert*-butyl-4-(15-methanesulphonyl-4,7,10,13-tetraoxapentadecyl)phenyl carbonate (1.54 g, 2.5 mmol) and NaN<sub>3</sub> (370 mg, 6.0 mmol) in DMF (10 mL) was heated to 90°C for 17 h. After cooling, the reaction mixture was poured into EtOAc (30 mL) and washed with water (3 x 30 mL), dried (Na<sub>2</sub>SO<sub>4</sub>) then concentrated *in vacuo* to give the *product* (1.3 g, 92 %) as an orange oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 2958, 2869, 2104, 1757, 1599, 1368, 1274, 1154, 1114, 891 and 783; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.36 (18H, s), 1.51 (9H, s), 1.88 (2H, pent,  $J$  8.0 Hz), 2.62 (2H, t,  $J$  8.0 Hz), 3.37 (2H, t,  $J$  6.0 Hz), 3.49 (2H, t,  $J$  6.0 Hz), 3.60 (2H, m), 3.66 (12H, m), 7.09 (2H, s).

*tert*-Butyl 2,6-di-*tert*-butyl-4-(15-amino-4,7,10,13-tetraoxapentadecyl)phenyl carbonate



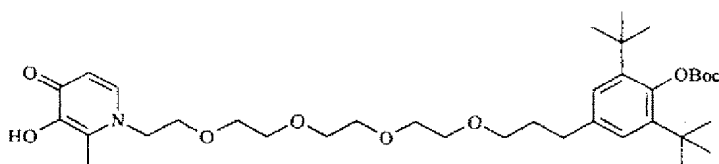
A suspension of *tert*-butyl 2,6-di-*tert*-butyl-4-(15-amino-4,7,10,13-tetraoxapentadecyl)phenyl carbonate (1.3 g, 2.3 mmol) and  $\text{PtO}_2$  (300 mg) in EtOH (20 mL) was stirred under a  $\text{H}_2$  atmosphere for 24 h. The solution was filtered and concentrated to give the *product* (1.2 g, 97 %) as a brown oil: IR  $\nu_{\text{max}}$  ( $\text{CDCl}_3$  smear)/ $\text{cm}^{-1}$  3441, 2961, 2872, 1757, 1599, 1456, 1368, 1274, 1257, 1154, 1114 and 891; NMR  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 1.35 (18H, s), 1.51 (9H, s), 1.89 (2H, m), 2.62 (2H, t,  $J$  7.5 Hz), 2.87 (2H, t,  $J$  5.5 Hz), 3.52 (2H, m), 3.67 (14H, m), 7.09 (2H, s);  $m/z$  (ES+) 540 (100%).

*tert*-Butyl 4-(15-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13-tetraoxapentadecyl)-2,6-di-*tert*-butylphenyl carbonate



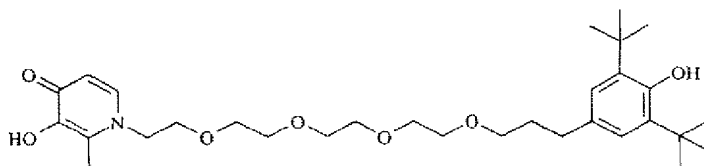
This was prepared from *tert*-butyl 2,6-di-*tert*-butyl-4-(15-amino-4,7,10,13-tetraoxapentadecyl)phenyl carbonate according to the method described in Example 6 to give the *product* (300 mg, 17 %) as an orange oil: IR  $\nu_{\text{max}}$  (film)/ $\text{cm}^{-1}$  2925, 1755, 1627, 1564, 1368, 1274, 1256, 1154, 1114, and 733; NMR  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 1.36 (18H, s), 1.52 (9H, s), 1.88 (2H, m), 2.12 (3H, s), 2.62 (2H, t,  $J$  8 Hz), 3.4-3.7 (16H, m), 3.92 (2H, t,  $J$  5 Hz), 5.21 (2H, s), 6.49 (1H, d,  $J$  7 Hz), 7.09 (2H, s), 7.28-7.42 (6H, m);  $m/z$  (ES+) 738 (100%).

*tert*-Butyl 4-(15-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13-tetraoxapentadecyl)-2,6-di-*tert*-butylphenyl carbonate



This was prepared from *tert*-butyl 4-(15-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13-tetraoxapentadecyl)-2,6-di-*tert*-butylphenyl carbonate according to the method described in Example 1. Column chromatography [ $\text{SiO}_2$ ;  $\text{CH}_2\text{Cl}_2$  : MeOH (95:5)] gave the *product* (130 mg, ~49 %) as an orange oil. This product contained a small amount of material resulting from additional loss of the Boc protecting group. As this impurity was the ultimate product required in the next step the material was used without further purification. IR  $\nu_{\text{max}}$  (film)/ $\text{cm}^{-1}$  2957, 2871, 1752, 1627, 1579, 1367, 1274, 1236, 1153 and 1114; NMR  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 1.36 (18H, s), 1.52 (9H, s), 1.88 (2H, m), 2.12 (3H, s), 2.62 (2H, t,  $J$  8 Hz), 3.4-3.7 (16H, m), 3.92 (2H, t,  $J$  5 Hz), 6.49 (1H, d,  $J$  6.5 Hz), 7.09 (2H, s), 7.43 (1H, m);  $m/z$  (ES+) 648 (100%).

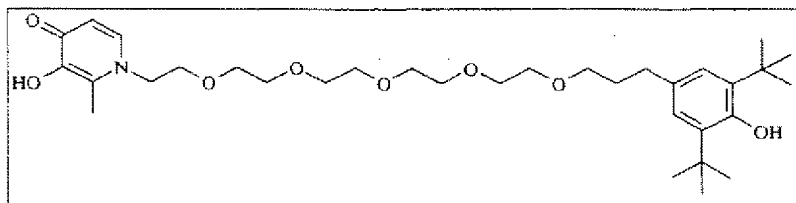
1-(15-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)-3,6,9,12-tetraoxapentadecyl)-3-hydroxy-2-methyl-4(1H)-pyridinone



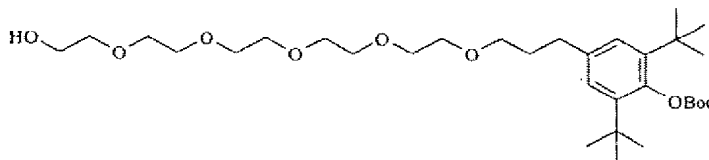
A solution of *tert*-butyl 4-(15-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13-tetraoxapentadecyl)-2,6-di-*tert*-butylphenyl carbonate (130 mg, 0.2 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (15 mL) was treated with TFA (0.3 mL) and stirred at room temperature for 4 h. The reaction mixture was poured into CH<sub>2</sub>Cl<sub>2</sub> (15 mL), washed cautiously with a saturated K<sub>2</sub>CO<sub>3</sub> solution, dried (Na<sub>2</sub>SO<sub>4</sub>) then concentrated *in vacuo* to give the *title compound* (95 mg, 86 %) as a pink oil: IR  $\nu_{\max}$  (film)/cm<sup>-1</sup> 3442, 2924, 2870, 1633, 1507, 1457, 1436, 1384 and 1145; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.41 (18H, s), 1.87 (2H, m), 2.42 (3H, s), 2.56 (2H, t, *J* 8 Hz), 3.48 (2H, t, *J* 8 Hz), 3.5-3.75 (14H, m), 4.10 (2H, m), 6.52 (1H, d, *J* 6.5 Hz), 6.96 (2H, s), 7.39 (1H, d, *J* 6.5 Hz); *m/z* (ES<sup>+</sup>) 548 (100%).

#### Example 14

[0152] 1-(18-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)-3,6,9,12,15-pentaoxaoctadecyl)-3-hydroxy-2-methyl-4(1*H*)-pyridinone

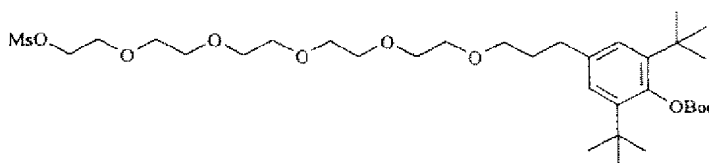


*tert*-Butyl 2, 6-di-*tert*-butyl-4-(18-hydroxy-4,7,10,13,16-pentaoxaoctadecyl)phenyl carbonate



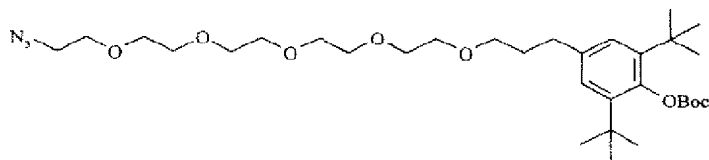
This was prepared from pentaethylene glycol according to the method described in Example 13 to give the *product* (2.40 g, 41 %) as an orange oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 3426, 2920, 2872, 1779, 1757, 1456, 1368, 1274, 1257, 1155, 1114 and 891; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.34 (18H, s), 1.52 (9H, s), 1.88 (2H, pent, *J* 8.0 Hz), 2.61 (2H, t, *J* 8.0 Hz), 3.49 (2H, t, *J* 8.0 Hz), 3.58-3.72 (20H, m), 7.09 (2H, s); *m/z* (CI, NH<sub>3</sub>) (MNH<sub>4</sub><sup>+</sup>) 603 (100%).

*tert*-Butyl 2, 6-di-*tert*-butyl-4-(18-methanesulphonyl-4,7,10,13,16-pentaoxaoctadecyl)phenyl carbonate



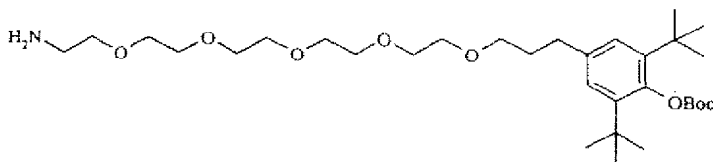
This was prepared from *tert*-butyl 2,6-di-*tert*-butyl-4-(18-hydroxy-4,7,10,13,16-pentaoxaoctadecyl)phenyl carbonate according to the method described in Example 13 to give the *product* (2.30 g, 85%) as an orange oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 2914, 2873, 1756, 1456, 1352, 1276, 1155, 1114 and 922; NMR  $\delta_{\text{H}}$  (400 MHz, CDCl<sub>3</sub>) 1.35 (18H, s), 1.54 (9H, s), 1.90 (2H, pent, *J* 8.0 Hz), 2.62 (2H, t, *J* 8.0 Hz), 3.07 (3H, s), 3.51 (2H, t, *J* 6.0 Hz), 3.61 (16H, m), 3.76 (2H, m), 4.39 (2H, m), 7.09 (2H, s).

*tert*-Butyl 2,6-di-*tert*-butyl-4-(18-azido-4,7,10,13-pentaoxaoctadecyl)phenyl carbonate



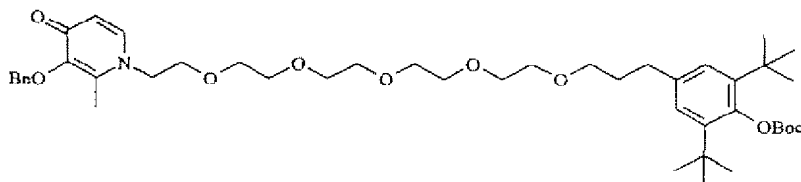
This was prepared from *tert*-butyl 2,6-di-*tert*-butyl-4-(18-methanesulphonyl-4,7,10,13,16-pentaoxaoctadecyl)phenyl carbonate according to the method described in Example 13 to give the *product* (1.93 g, 92 %) as an orange oil: IR  $\nu_{\max}$  (liquid film)/cm<sup>-1</sup> 2920, 2870, 2106, 1757, 1457, 1395, 1368, 1275, 1154 and 1114; NMR  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 1.37 (18H, s), 1.52 (9H, s), 1.91 (2H, pent, *J* 8.0 Hz), 2.62 (2H, t, *J* 8.0 Hz), 3.38 (2H, t, *J* 6.0 Hz), 3.49 (2H, t, *J* 6.0 Hz), 3.60 (2H, m), 3.66 (16H, m), 7.09 (2H, s).

*tert*-Butyl 2, 6-di-*tert*-butyl-4-(18-amino-4,7,10,13,16-pentaoxaoctadecyl)phenyl carbonate



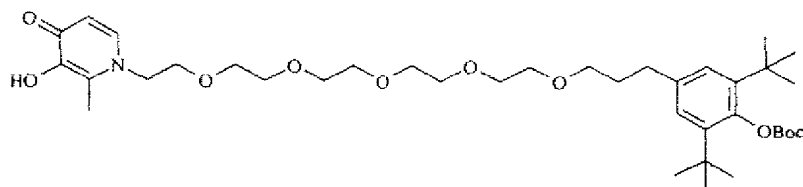
This was prepared from *tert*-butyl 2,6-di-*tert*-butyl-4-(18-azido-4,7,10,13-pentaoxaoctadecyl)phenyl carbonate according to the method described in Example 13 to give the *product* (1.8 g, 98 %) as a brown oil: IR  $\nu_{\max}$  (film)/cm<sup>-1</sup> 3374, 2952, 2870, 1757, 1368, 1274, 1257, 1155 and 1114; NMR  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 1.35 (18H, s), 1.51 (9H, s), 1.89 (2H, m), 2.62 (2H, t, *J* 7.5 Hz), 2.91 (2H, t, *J* 5.5 Hz), 3.51 (2H, m), 3.67 (18 H, m), 7.09 (2H, s); *m/z* (ES<sup>+</sup>) 584 (50%), 484 (100).

*tert*-Butyl 4-(18-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13,16-pentaoxaoctadecyl)-2,6-di-*tert*-butylphenyl carbonate



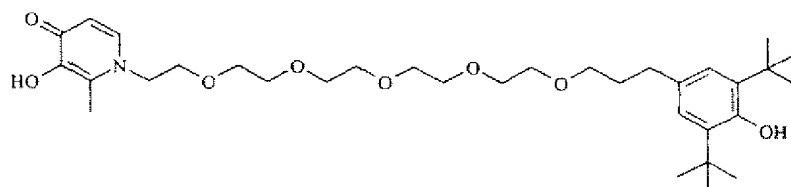
This was prepared from *tert*-butyl 2,6-di-*tert*-butyl-4-(18-amino-4,7,10,13,16-pentaoxaoctadecyl)phenyl carbonate according to the method described in Example 6 to give the *product* (270 mg, 11 %) as an orange oil: IR  $\nu_{\max}$  (film)/cm<sup>-1</sup> 3063, 2954, 2870, 1756, 1628, 1566, 1367, 1274, 1256, 1154, 1114 and 753; NMR  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 1.36 (18H, s), 1.53 (9H, s), 1.88 (2H, m), 2.16 (3H, s), 2.62 (2H, t, *J* 8 Hz), 3.4-3.7 (20H, m), 3.98 (2H, m), 5.24 (2H, s), 7.09 (2H, s), 7.34-7.45 (7H, m); *m/z* (ES<sup>+</sup>) 783 (100%), 727 (10).

*tert*-Butyl 4-(18-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13,16-pentaoxaoctadecyl)-2,6-di-*tert*-butylphenyl carbonate



This was prepared from *tert*-butyl 4-(18-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13,16-pentaoxaoctadecyl)-2,6-di-*tert*-butylphenyl carbonate according to the method described in Example 1 to give the *product* (230 mg, 96 %) as a brown oil. This product contained a small amount of material resulting from additional loss of the Boc

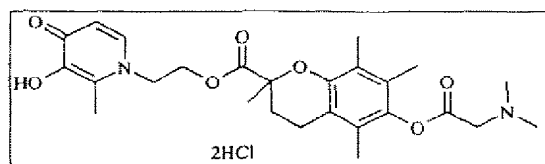
protecting group. As this impurity was the ultimate product required in the next step the material was used without further purification: NMR  $\delta_H$  (400 MHz,  $CDCl_3$ ) 1.36 (18H, s), 1.52 (9H, s), 1.88 (2H, m), 2.12 (3H, s), 2.62 (2H, t,  $J$  8 Hz), 3.4-3.7 (20 H, m), 4.10 (2H, m), 6.49 (1H, d,  $J$  6.5 Hz), 7.09 (2H, s), 7.38 (1H, d,  $J$  6.5 Hz);  $m/z$  (ES+) 692 (100%).



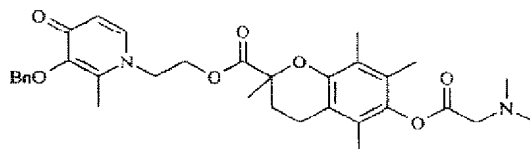
This was prepared from *tert*-butyl 4-(18-(1,4-dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)-4,7,10,13,16-pentaoxa-octadecyl)-2,6-di-*tert*-butylphenyl carbonate according to the method described in Example 13 to give the *title compound* (170 mg, 87 %) as an orange oil: IR  $\nu_{max}$  ( $CH_2Cl_2$ )/ $cm^{-1}$  2954, 2872, 1754, 1689, 1629, 1566, 1582, 1508, 1436, 1360, 1265 and 1119; NMR  $\delta_H$  (400 MHz,  $CDCl_3$ ) 1.44 (18H, s), 1.89 (2H, m), 2.40 (3H, s), 2.59 (2H, t,  $J$  8 Hz), 3.50 (2H, t,  $J$  8 Hz), 3.5-3.75 (18H, m), 4.05 (2H, m), 6.32 (1H, d,  $J$  8 Hz), 6.97 (2H, s), 7.31 (1H, d,  $J$  8 Hz);  $m/z$  (ES+) 592 (100%).

### Example 15

[0153] 2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl-3,4-dihydro-6-(*N,N*-dimethylaminoacetoxy)-2,5,7,8-tetramethyl-2*H*-benzopyran-2-carboxylate dihydrochloride

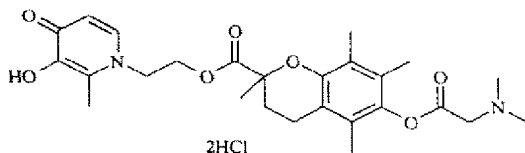


[0154] 2-(3-Benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl-3,4-dihydro-6-(*N,N*-dimethylaminoacetoxy)-2,5,7,8-tetramethyl-2*H*-benzopyran-2-carboxylate



To a stirred solution of 2-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl 3,4-dihydro-6-hydroxy-2,5,7,8-tetramethyl-2*H*-benzopyran-2-carboxylate (1.84 mmol) in dry pyridine (10 mL) under argon at 0°C is added *N,N*-dimethylglycyl chloride hydrochloride (0.58 g, 3.68 mmol). The suspension is stirred under argon at room temperature for 24 h and then heated at 70°C for 48 h. After cooling, the reaction mixture is evaporated *in vacuo*. The residue is partitioned between  $CH_2Cl_2$  (40 mL) and water (40 mL). The organic phase is separated, washed with water (30 mL) and brine (30 mL), dried ( $MgSO_4$ ) and evaporated *in vacuo*. The crude material is purified by chromatography [ $SiO_2$ ;  $CHCl_3$ : MeOH:AcOH (90:8:2)] to give the *product*.

[0155] 2-(1,4-Dihydro-3-hydroxy-2-methyl-4-oxo-1-pyridinyl)ethyl 3,4-dihydro-6-(*N,N*-dimethylaminoacetoxy)-2,5,7,8-tetramethyl-2*H*-benzopyran-2-carboxylate dihydrochloride



This is prepared from 2-(3-benzyloxy-1,4-dihydro-2-methyl-4-oxo-1-pyridinyl)ethyl 3,4-dihydro-6-(N,N-dimethylaminoacetox)-2,5,7,8-tetramethyl-2H-benzopyran-2-carboxylate according to the method described in Example 2 to produce the *title compound*.

#### Biological Testing Procedures and Data

**[0156]** The ability of the compounds of the present invention to protect against oxidative damage has been shown in both *in vitro* and *in vivo* models. These models are briefly explained below.

#### **Lipid Peroxidation assay**

**[0157]** Lipid peroxidation in rat brain homogenates is a general procedure used to measure the antioxidant capacity of molecules in a biological environment (Das N.P. and Ratty A.K., *Biochem. Med. Metab. Biol.* 1987, 37, 256-264). Compounds of the present invention have been shown to be potent inhibitors of lipid peroxidation.

#### **Iodoacetate induced cell toxicity in culture**

**[0158]** Iodoacetate, via its alkylation of glyceraldehyde-3-phosphate dehydrogenase (GAPDH), is a potent inhibitor of glycolysis and hence energy production in cells. This form of chemical hypoxia has been demonstrated to result in a state of oxidative stress, from which the cells can be rescued by anti-oxidant molecules (Uto A. *et al.*, *J. Neurochem.* 1995, 64, 2185-2192; Malcolm C.S. *et al.*, *Soc. Neurosci.*, 1998, Abstr. 570.21). The compounds of the present invention have been shown to protect cerebellar granule cells from this chemical induced oxidative stress.

#### **Malonic Acid lesion model**

**[0159]** Malonic acid is a competitive inhibitor of succinate dehydrogenase. It depletes extracellular ATP production, and intrastriatal injection has previously been demonstrated to cause a NMDA receptor mediated lesion (Greene *et al.*, *J. Neurochem.*, 1993, 61, 1151-1154). Compounds of the present invention have shown neuroprotective ability in this animal model of oxidative stress.

### **1. In Vitro Assays**

#### **1a. Lipid Peroxidation**

##### Procedure

**[0160]** Rat cortex was homogenised in 20 vols. of ice cold 0.32-M sucrose and centrifuged at 1,000 g for 10 min. The pellet was discarded whilst the resulting supernatant was centrifuged at 15,000 g for 20 min at 4 °C to yield p<sub>2</sub> pellets. The pellet was re-suspended in ice-cold 50.0-mM phosphate buffer and centrifuged at 30,000 g for 20 min at 4 °C. The pellet was re-suspended in 30 vols. of 50.0-mM phosphate buffer and used immediately in the assay.

**[0161]** Assays contained 500-μM L-ascorbic acid to induce lipid peroxidation, plus various concentrations of test compound, with the tissue preparation in a total volume of 500 μL. This was incubated at 37 °C for 30 min. Lipid peroxidation was measured by adding to the reaction mixture, 300 μL 40 % (w/v) trichloroacetic acid, 150 μL 5.0-M HCl and 300 μL 2 % (w/v) 2-thiobarbituric acid (TBA). Samples were then heated at 90 °C in a water bath for 15 min, and centrifuged at 15,000 g for 10 min. The pink colour of the supernatant was assessed spectrophotometrically at a wavelength of 532 nm. The amount of malondialdehyde (MDA) in the samples was calculated using a standard curve prepared with malondialdehyde tetrabutylammonium salt (Das, N.P. and Ratty, A.K. *Biochem. Med. Metab. Biol.* 1987, 37, 256-264).

Data

[0162] Results are expressed as  $IC_{50}$  values ( $\mu M$ ) and presented in Table 1. The  $IC_{50}$  values show the concentration of test compound required to inhibit the lipid peroxidation by 50%.

Table 1

Lipid Peroxidation	
Compound Example No.	$IC_{50}$ ( $\mu M$ )
Example 1	0.2
Example 2	0.2
Example 3	1.5
Example 4	1.0
Example 5	0.8
Example 6	0.2
Example 7	0.1
Example 8	0.5
Example 9	0.4
Example 10	0.2

[0163] The results demonstrate that the compounds of the present invention inhibit the peroxidation of lipid membranes induced by ascorbic acid.

**1b Cell Death**Procedure

[0164] After 6-8 days in culture, cerebellar granule cell (CGC) cultures in 96-well plates (250,000 cells per well) were prepared for hypoglycaemia. Iodoacetate (IAA) was made up in a balanced salt solution (BSS) (NaCl, 154.0-mM; KCl, 5.6-mM;  $MgCl_2$ , 1.0-mM;  $CaCl_2$ , 2.5-mM; N-[2-hydroxyethyl]piperazine-N'-[2-ethanesulfonic acid] (HEPES), 10.0-mM; D-glucose, 5.6-mM; pH 7.4) and any neuroprotective agents were made up in pre-warmed tissue culture media and allowed to equilibrate in a controlled environment (5 %  $CO_2$ , 95 % air). The assay was initiated by aspiration of the maintenance media, which was replaced by either BSS (control) or 30- $\mu M$  IAA in BSS, both solutions containing 10- $\mu M$  of the NMDA receptor antagonist MK-801. The exposure to IAA was for 30 min only at 37 °C, after which time the BSS was aspirated and replaced with fresh, pre-equilibrated maintenance media containing various concentrations of test compound. All conditions were performed at least in duplicate in each 96 well plate. The final volume for each well was always 200  $\mu L$ . Following a 24 hour incubation, visual inspection of the cells was followed by quantification of neuronal cell death by measuring 3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide (MTT)-reductase activity as described previously (Malcolm *et al.*, J. Neurochem. 1996, 66, 2350-2360).

Data

[0165] Results are expressed as  $EC_{50}$  values ( $\mu M$ ) and presented in Table 2.

Table 2

Cell Toxicity	
Compound	$EC_{50}$ ( $\mu M$ )
Example 1	0.3
Example 2	3.3
Example 3	1.8

Table 2 (continued)

Cell Toxicity	
Compound	EC <sub>50</sub> (μM)
Example 4	1.8
Example 5	2.6
Example 6	~3.0
Example 7	0.6
Example 8	3.8
Example 9	1.6
Example 10	~5.3

[0166] The results demonstrate the protective effect of the compounds of the invention on neuronal cells exposed to oxidative damage induced by IAA.

### 1 c. Measurement of oxidative stress

#### Procedure

[0167] Intracellular oxidative stress was measured using the oxidant-sensitive fluorescent dye 2',7'-dichlorodihydrofluorescein diacetate (DCFH-DA) (Molecular Probes). The non-fluorescent DCFH-DA readily crosses cell membranes whereupon it is trapped within the cytoplasm by deacetylation to the non-membrane permeable form dichlorodihydrofluorescein (DCFH). Upon oxidation, DCFH yields the highly fluorescent product dichlorofluorescein (DCF). Briefly, growth medium was aspirated from cultures and replaced with 200 μl BSS (plus 10.0-μM MK-801) or BSS (plus 10.0-μM MK-801) containing 30.0-μM IAA alone or in combination with various concentrations of antioxidants. After incubation at 37 °C for 30 minutes, cultures were aspirated once more and 10.0-μM DCFH-DA (200 μL) added to all wells. After a further 20 minute incubation at 37 °C, fluorescence was measured in a Cytofluor II fluorescent plate reader (λ<sub>ex</sub>=485nm; λ<sub>em</sub>=530nm). Background fluorescence values from wells treated with 2 % Triton X-100 were subtracted from both basal and stimulated fluorescence values and the effects of test compounds expressed as a percent inhibition of the IAA-stimulated fluorescence increase over basal.

#### Data

[0168] Results are expressed as EC<sub>50</sub> values (μM) and presented in Table 3. The EC<sub>50</sub> value gives the effective concentration of test compound required to block the oxidation of DCFH to DCF by 50%. The EC<sub>50</sub> value is derived from Figure 1 by extrapolating from the point at which the fluorescence value is reduced to 50% of its original maximum value. Figure 1 shows IAA-stimulated fluorescence values as a function of concentration for Example 10.

Table 3

Oxidative Stress	
Compound	EC <sub>50</sub> (μM)
Example 10	0.8

[0169] The results demonstrate that the compounds of the invention inhibit oxidation of DCFH to DCF in a similar manner to that of their inhibition of IAA-induced cell death. This confirms that the neuronal toxicity induced by IAA is a result of oxidative stress, and that the compounds of the present invention protect neuronal cells from oxidative stress.



1. In Vivo Assay**Malonic Acid Lesion Model**Procedure

[0170] Malonic acid is a competitive inhibitor of succinate dehydrogenase, a key enzyme in both the tricarboxylic acid cycle and oxidative phosphorylation. Injection of malonic acid into the striatum causes ATP depletion, resulting in an excitotoxic lesion (Greene *et al.*, J. Neurochem., 1993, 61, 1151-1154). 2  $\mu$ L of a 0.5-M malonic acid solution is injected into the right striatum of rats, with or without test compounds. 24 hours after surgery the animals are sacrificed and the size of the lesion measured using TTC histochemistry.

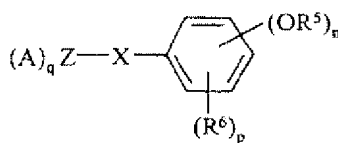
Data

[0171] The observed activity of the compound of Example 2 is displayed in Figure 2. 7.7 ng of the compound is the equivalent of 2  $\mu$ L of a 10.0- $\mu$ M solution. 23.2 ng of the compound is the equivalent of 2  $\mu$ L of a 30.0- $\mu$ M solution. 77.3 ng of the compound is the equivalent of 2  $\mu$ L of a 100.0- $\mu$ M solution.

[0172] The results demonstrate that the compounds of the present invention have neuroprotective ability in an animal model of oxidative stress.

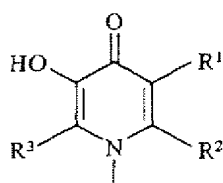
**Claims**

1. A compound of the formula (1):



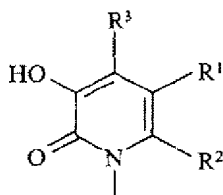
(I)

wherein A is



(AI)

or



(AII)

wherein  $R^1$ ,  $R^2$  and  $R^3$  are independently selected from H and alkyl;  
 wherein X is O, S,  $NR^4$  or a direct bond, wherein  $R^4$  is H or alkyl;  
 wherein Z is a saturated hydrocarbyl chain comprising from 1 to 20 carbon atoms interrupted by one or more heteroatom(s) and optionally substituted by one or more oxo substituent(s);  
 wherein q is 1, 2 or 3;  
 wherein if q is 2 or 3, then each A can be the same or different;  
 wherein the or each  $R^5$  is independently selected from H and alkyl;  
 wherein the or each  $R^6$  is independently selected from alkyl;  
 wherein n is 1 to 5;  
 wherein p is 0 to 4; and  
 wherein the sum of n and p is less than 6.

or a pharmaceutically acceptable salt thereof.

2. A compound according to claim 1 wherein  $R^1$ ,  $R^2$  and  $R^3$  are independently selected from H and unsubstituted alkyl.
3. A compound according to claim 1 wherein A is Al and  $R^2$  and  $R^3$  are independently selected from H, unsubstituted alkyl,  $CH_2OR^7$ ,  $CH_2OCOR^7$ ,  $COOR^7$ ,  $CH_2NHR^7$ ,  $CH_2NHCOR^7$  and  $CONHR^7$  wherein  $R^7$  is selected from H and alkyl.
4. A compound according to claim 3 wherein  $R^1$  is H or unsubstituted alkyl.
5. A compound according to claim 1 wherein A is Al and  $R^1$  and  $R^2$  are H and  $R^3$  is unsubstituted alkyl.
6. A compound according to claim 1, 2, 3, 4 or 5 wherein  $R^3$  is methyl.
7. A compound according to claim 1 wherein A is All and  $R^1$ ,  $R^2$  and  $R^3$  are independently selected from H, unsubstituted alkyl,  $CH_2OR^7$ ,  $CH_2OCOR^7$ ,  $COOR^7$ ,  $CH_2NHR^7$ ,  $CH_2NHCOR^7$  and  $CONHR^7$  wherein  $R^7$  is selected from H and alkyl.
8. A compound according to claim 1 wherein A is All, and  $R^1$ ,  $R^2$  and  $R^3$  are H.
9. A compound according to any one of claims 1 to 8 wherein q = 1.
10. A compound according to any one of claims 1 to 9 wherein Z is a saturated hydrocarbyl chain comprising from 1 to 20 carbon atoms interrupted by one or more group(s) selected from O, S, SO,  $SO_2$ ,  $SO_2NH$ ,  $NHSO_2$ , NH,  $NHCO$ ,  $CONH$ ,  $NHCONH$ ,  $NHCOO$ ,  $OCONH$ ,  $OCO$  and  $COO$ .
11. A compound according to any one of claims 1 to 10 wherein Z is  $(CH_2)_k W (CH_2)_m$ , wherein k and m are independently 0 to 20; wherein  $1 \leq (k+m) \leq 20$ ; and wherein W is selected from O, S, SO,  $SO_2$ ,  $SO_2NH$ ,  $NHSO_2$ , NH,  $NHCO$ ,  $CONH$ ,  $HCONH$ ,  $NHCOO$ ,  $OCONH$ ,  $OCO$  and  $COO$ .
12. A compound according to claim 11 wherein k is 1, 2, 3 or 4 and m is 1, 2, 3 or 4.
13. A compound according to claim 11 wherein:

when k is 0, W is selected from O, NH, NHCO, NHCONH, NHCOO and OCONH, or  
 when k is 1, W is selected from SO, SO<sub>2</sub>, SO<sub>2</sub>NH, CONH and COO; or  
 when m is 0 and X is a direct bond, W is selected from O, S, SO<sub>2</sub>NH, NH, CONH, NHCONH, NHCOO, OCONH  
 and COO; or  
 when m is 0 and X is O, S or NR<sup>4</sup>, W is selected from SO, SO<sub>2</sub>, NHSO<sub>2</sub> and NHCO; or  
 when m is 1 and X is O, S or NR<sup>4</sup>, W is selected from SO, SO<sub>2</sub>, NHSO<sub>2</sub> and NHCO, OCO.

14. A compound according to any one of claims 1 to 13 wherein Z comprises from 1 to 13 carbon atoms.
15. A compound according to any one of claims 1 to 13 wherein Z comprises from 1 to 10 carbon atoms.
16. A compounds according to any one of claims 1 to 13 wherein Z comprises from 1 to 8 carbon atoms.
17. A compound according to any one of claims 1 to 16 wherein X is O, S or a direct bond.
18. A compound according to any one of claims 1 to 16 wherein X is NR<sup>4</sup> and R<sup>4</sup> is alkyl.
19. A compound according to claim 18 wherein R<sup>4</sup> is cyclised on to the chain defined as Z.
20. A compound according to any one of the previous claims wherein R<sup>5</sup> is selected from H and C<sub>1-10</sub> alkyl.
21. A compound according to any one of the previous claims wherein at least one R<sup>5</sup> is H.
22. A compound according to any one of the previous claims wherein R<sup>6</sup> is methyl, isopropyl or t-butyl.
23. A compound according to any of claims 1 to 18 wherein R<sup>5</sup> is alkyl and is cyclised onto the chain defined as Z.
24. A compound according to any of claims 1 to 18 wherein R<sup>6</sup> is alkyl and is cyclised onto the chain defined as Z.
25. A compound according to any one of claims 1 to 24 for use in therapy.
26. Use of a compound according to any one claims 1 to 24 in the manufacture of a medicament for the treatment of a condition associated with oxidative stress.
27. A method of treating a condition associated with oxidative stress comprising administering to a patient in need of such treatment an effective dose of a compound according to any one of claims 1 to 24.
28. A use or method according to claim 26 or 27 wherein said oxidative stress is oxidative damage of the central nervous system.
29. A use or method according to claim 26 or 27 wherein said condition is an acute or chronic neurological disorder.
30. A use or method according to claim 29 wherein said neurological disorder is traumatic brain injury, spinal cord injury, cerebral tumour, subharrachnoid haemorrhage/cerebral vasospasm, cerebral ischaemia, stroke (ischaemic or haemorrhagic), Alzheimer's disease, Huntington's Disease, Parkinson's Disease, Friedrich's ataxia, motor neuron disease or multiple sclerosis.
31. A pharmaceutical composition comprising a compound according to any one of claims 1 to 24 in combination with a pharmaceutically acceptable carrier or excipient.

Figure 1

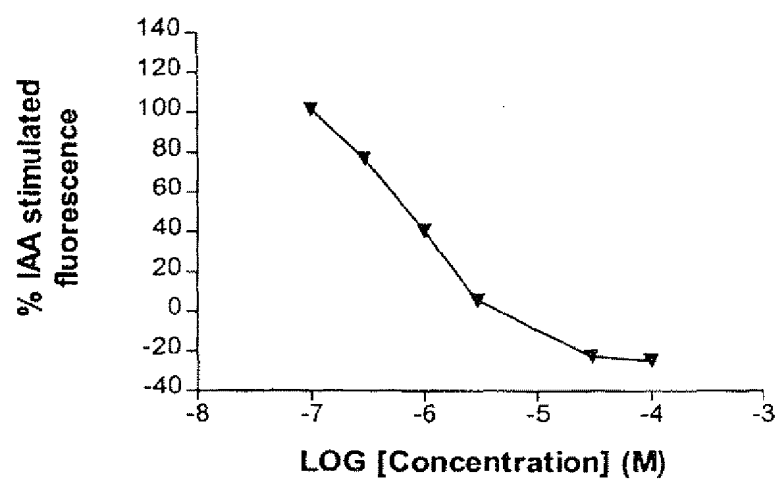
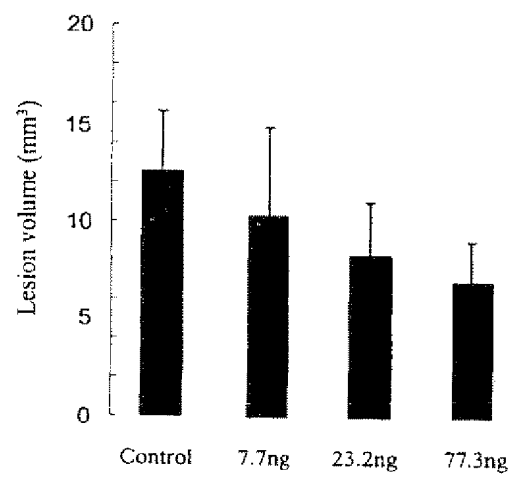


Figure 2





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# PARTIAL EUROPEAN SEARCH REPORT

Application Number

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

EP 99 30 9637

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X,P	WO 99 23075 A (GAUR SUNEEL ;MALCOLM CRAIG (GB); MONCK NAT (GB); PALMER ALAN (GB);) 14 May 1999 * claims; examples 6-9 *	1,25-31	C07D213/69 A61K31/4412 A61P25/00 C07D405/12
X,P	DATABASE CHEMABS CHEMICAL ABSTRACTS SERVICE, COLUMBUS, OHIO, US LIU, ZU DONG ET AL: "In Vivo iron mobilization evaluation of hydroxypyridinones in 59Fe-ferritin-loaded rat model" XP002132365 * CAS RN 223647-31-2 * * claims; examples 6-9 * & BIOCHEM. PHARMACOL. (1999), 57(5), 559-566, --- -/-	1,25-31	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			C07D A61K A61P
<b>INCOMPLETE SEARCH</b>			
<p>The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.</p> <p>Claims searched completely:</p> <p>Claims searched incompletely:</p> <p>Claims not searched:</p> <p>Reason for the limitation of the search:</p> <p>Although claims 27-30 are directed to a method of treatment of the human/animal body (Article 52(4) EPC), the search has been carried out and based on the alleged effects of the compound/composition.</p>			
Place of search		Date of completion of the search	Examiner
THE HAGUE		7 March 2000	Bosma, P
CATEGORY OF CITED DOCUMENTS			
<p>X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document</p>		<p>T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons &amp;: member of the same patent family, corresponding document</p>	

EPO FORM 1503 03.02 (P04/2007)



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# PARTIAL EUROPEAN SEARCH REPORT

Application Number  
EP 99 30 9637

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (InLCL7)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	CHEMICAL ABSTRACTS, vol. 129, no. 14, 5 October 1998 Columbus, Ohio, US; abstract no. 171647, GOMEZ, MERCEDES ET AL: "Aluminum distribution and excretion: A comparative study of a number of chelating agents in rats" XP002132364 * 1-(p-methoxybenzyl)-2-methyl-3-hydroxypyrid-4-one * * claims; examples 6-9 * & PHARMACOL. TOXICOL. (COPENHAGEN) (1998), 82(6), 295-300,	1,25-31	
A	WO 98 25905 A (CENES LIMITED ;HIDER ROBERT CHARLES (GB); MORIDANI MAJID YOUSEFI ( ) 18 June 1998 * the whole document; claims; examples 6-9 *	1,25-31	TECHNICAL FIELDS SEARCHED (InLCL7)

EPO FORM 1203 02.02 (P01C10)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 99 30 9637

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
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07-03-2000

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9923075	A	14-05-1999	AU	9638098 A	24-05-1999
WO 9825905	A	18-06-1998	AU	7847198 A	03-07-1998

EPC FORM P450

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82